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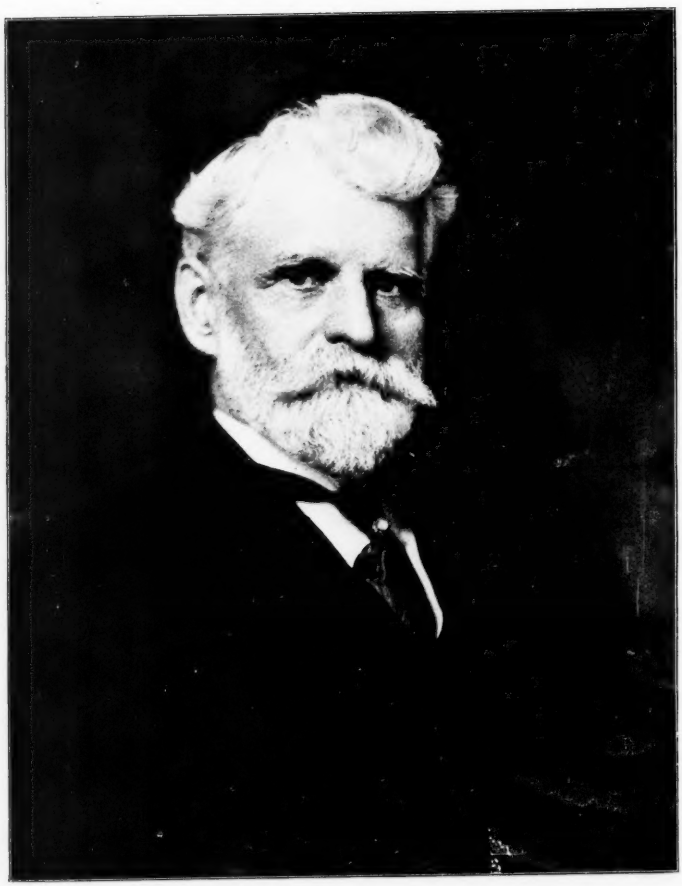
GRANVILLE, OHIO, JULY, 1911



Ambrose Swasey, Donor of the Swasey Observatory

THE SWASEY OBSERVATORY, DENISON UNIVERSITY[1]

HERBERT C. WILSON

Director Goodsell Observatory of Carleton College

This new observatory was presented to Denison University by Mr. Ambrose Swasey, of Cleveland, and was dedicated on June 15, 1910. At the request of the editor of *Popular Astronomy*, the following information concerning the building and equipment was given by Mr. Swasey and by Mr. T. Milton Dyer, the architect by whom the observatory was designed. Owing to his great modesty, Mr. Swasey does not give much of an idea of the beauty, either of the exterior structure of white marble or the elegant interior finish. The observatory is admirably situated on a high ridge commanding a clear horizon, and is in all respects well adapted to both instruction and research.

In designing this observatory the aim was to produce a building which would adequately meet all the requirements of housing a small telescope with its accessories, and at the same time present an attractive exterior.

The small scale of the building necessitated a simple and flat treatment. The materials selected, both for the interior and exterior, are the most permanent and dignified. The exterior walls of white marble are crowned by a very small cornice, the moldings following classical lines.

The only entrance to the building is through the base of the main observation tower. This leads to a circular room, treated with a Tennessee marble floor, a high Grueby tile wainscot, with plaster walls and cornice above. In the center of the marble floor is a bronze plaque, with a conventional sun in the center and a border formed of the signs of the zodiac (fig. 2).

The walls above the wainscot are painted and over-glazed. A decorative frieze crowns this surface, and contains a running Biblical quotation: "The heavens declare the glory of God, and the firmament showeth His handiwork."

[1] Reprinted from *Popular Astronomy*, vol. xvii, no. 8, October, 1910.

Directly back of this circular room is a hall giving access to the stairs which lead to the telescope room, the library and transit room, dark room, toilet room and basement.

The transit room has a Tennessee marble floor and a light gray brick wainscot. The plaster walls above are painted in a tone slightly lighter than brick.

The library has a marble floor. The bookcases of oak, fumed, form a wainscot in this room, the plaster above being painted and overglazed in warm colors.

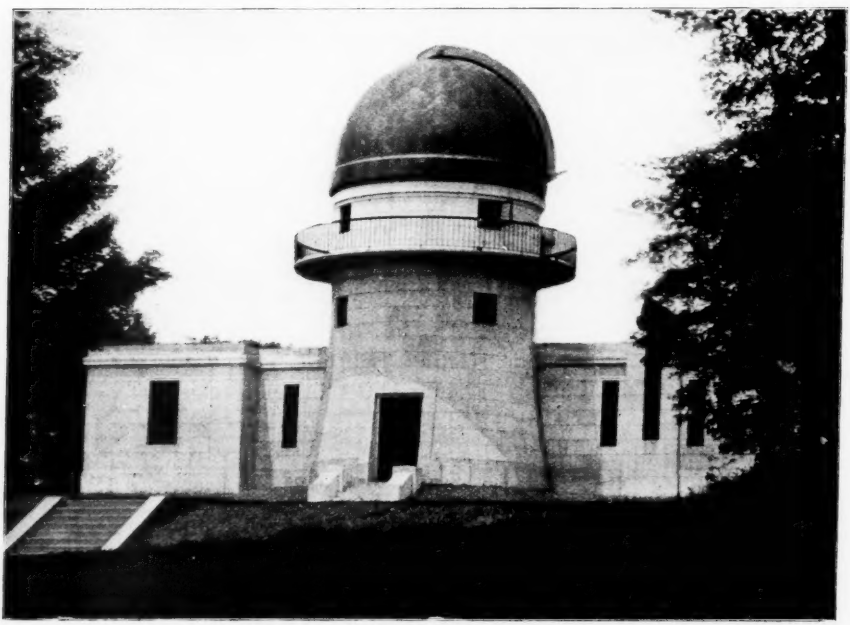


FIG. 1. The Swasey Observatory.

At the level of the telescope room and extending around the exterior of the building, is a gallery with light railing, affording a fine view over the broad valley spreading far below.

The equipment consists of a 9″ equatorial telescope; a 4″ transit and zenith telescope; a cylinder chronograph; two Riefler astronomical clocks; one Seth Thomas clock; switchboard with sounder, and all electrical connections.

The equatorial telescope is one of the standard Warner and Swasey type, similar in design to the 26″ telescope in the United States Naval Observatory, the 36″ Lick and the 40″ Yerkes, and others of similar size designed and constructed by that company.

The column supporting the equatorial head is of cast iron, rectangular in shape, with broad base, extending under the floor at the

FIG. 2

north side, and mounted on four heavy steel beams which are built into the walls to keep the instrument from contact with the floor.

The upper section of the iron column contains the driving clock, which is protected from dust and injury by plate glass doors. The lower part of the column is utilized for the driving weights which run the clock.

The equatorial head and the bearings for the polar axis are made in one casting. The coarse right ascension and declination circles have large graduations and figures on the face, and are easily read from the floor of the observatory. The fine circles are graduated on sterling silver, and are read by verniers and reading glasses, illumined by small incandescent electric lamps.

The driving clock is of the same pattern as those provided with the larger telescopes above mentioned. It is governed by a

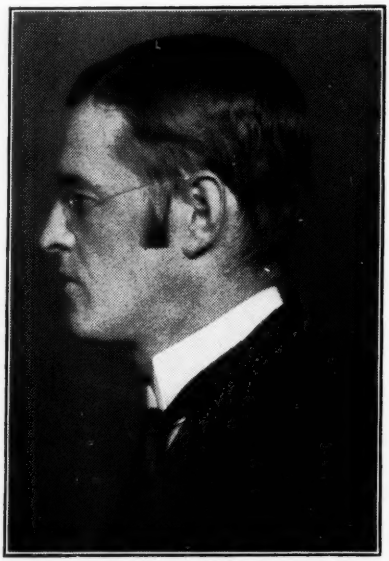


FIG. 3. Edwin Brant Frost, Director of the Yerkes Observatory. The address delivered by Professor Frost at the Dedication of the Swasey Observatory is printed in this number of the BULLETIN.

double conical pendulum mounted isochronously, making three revolutions per second, and its movement is connected with the polar axis by means of a continuous worm gear having 360 teeth.

The telescope tube is of sheet steel, very light and rigid. It is provided with right ascension and declination clamps and slow motions, which are governed by handles and knobs within easy reach of the observer. On the north side of the column is placed

a dial which is made to revolve in sidereal time by the equatorial driving clock. A double pointer on this dial is made to move in unison with the polar axis, thus enabling the observer to directly point the telescope to the right ascension of the star to be observed, with the same ease that it is set on the declination of the star. Under this sidereal dial on the north side of the column is a wheel with handles, connected with gearing to the polar axis, enabling the observer to easily set the telescope while reading the sidereal dial.

The optical parts of the telescope were all made by the John A. Brashear Company, of Pittsburgh, Pa. The objective has a clear aperture of 9″ and a focal length of 135″; and the finder has a clear aperture of 3″ and a focal length of 17½″.

In addition to the usual number of eye-pieces there is provided a diagonal prism for zenith observations; a helioscope for observing the sun, and a fine micrometer for measuring double stars.

The 4″ combined transit and zenith instrument is of the standard design with iron base and columns. It is provided with a universal micrometer with electric illumination showing dark wires on a bright field. The axis carries two circles 12″ in diameter, one to be used as a setting or finding circle, reading by opposite verniers to single minutes; the other divided upon coin silver with a fine level to read to ten seconds by two double opposite verniers.

The instrument is provided with a most perfect system of reversal, enabling it to be used not only as a transit instrument but as a zenith telescope.

The cylinder chronograph is provided with a driving clock controlled by a conical pendulum similar to that used in the 9″ telescope. It has a drum 7″ in diameter, and 14″ in length, on which is recorded the work done by the transit instrument. A carriage carrying the pen which makes the records is connected electrically with the sidereal clock, thereby making a record on the drum every second. From the same carriage electric wires are carried to the transit instrument, the contact being made by the observer as the star which is being observed crosses the spider lines in the micrometer. By this means a record within one-tenth of a second is permanently made on the sheet of paper carried by the drum. These records of the observer made on the drum during an evening can be computed at leisure by the astronomer.

In the library are two astronomical precision clocks made by Riefler and Munich. These are the finest clocks ever made, their record surpassing in exactness all other clocks. These clocks do not require winding as does an ordinary clock, for they are provided with a series of magnets, which by electric contact wind them every 34 or 38 seconds. A third clock is provided for the transit room, which is of the standard type made by the Seth Thomas Clock Company.

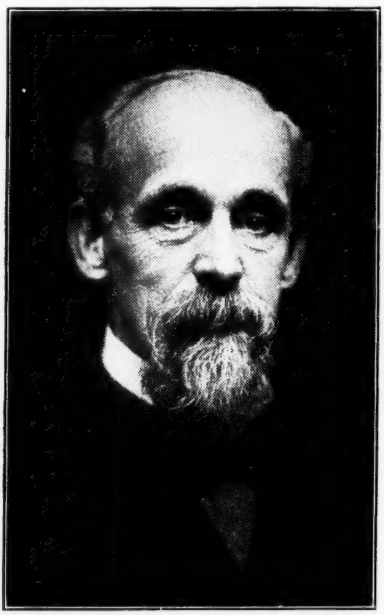


FIG. 4. John Alfred Brashear, Director of the Allegheny Observatory, who gave an address on *Resolutions of the Telescope* at the dedication of the Swasey Observatory.

The address of Doctor Brashear was a very illuminating and interesting discussion of the universe and the means of studying it, a sketch of the gradual progress of man's knowledge of the heavens. The intricate details of observatory equipment were made clear by means of numerous slides, and what has been done with this equipment was fully shown by other slides. The address was a masterful yet simple review of the great field of science to which the speaker has given most of his life.—EDITOR.

THE CONTRIBUTION OF ASTRONOMY TO GENERAL CULTURE[1]

EDWIN B. FROST

Director Yerkes Observatory of the University of Chicago

The word culture may be interpreted in such widely different ways, according to the points of view of different individuals, that its definition might properly be thought to be essential before I proceed with my remarks. I shall forego any such preliminary, however, and hope to use the term in so broad a way that it may include what anyone might mean by its use—learning, knowledge, or the enduring acquaintance with well-thought ideas.

I shall also refer to some of the influences of the study of this ancient branch of learning upon both the teacher and the taught, and the enlargement of mental horizons which its pursuit brings to those who may give much or little of their time to it.

It may be well to approach the matter in a somewhat historical manner, although progress here, as elsewhere, has not been steady, but intermittent, as the genius of some man has illumined here and there the pathway of knowledge. Had one the time for the necessary historical investigation, I believe it would not be difficult to trace the development of this or other branches of learning in such a way that the lives of students should overlap, in point of time, back to the earliest beginnings of recorded history. Thus we could picture the accretions of knowledge, and often of error, as handed on from one worker to another, of very different ability, in very different and perhaps distant lands, and with very unequal value in their separate contributions. Thus the astronomical progress of more than four centuries might be represented in the linkage of the lives of eight men, as follows:

	DIED		DIED
Copernicus	1543	Newton	1727
Apianus	1552	Halley	1742
Tycho	1601	W. Herschel	1822
Galileo	1642	F. G. W. Struve	1864

[1] Address delivered at the dedication of the Swasey Observatory, June 15, 1910.

It remains to me a singular fact that astronomy should have been one of the oldest of the sciences, even in superstitious ages. We should naturally think in the first place of agriculture meteorology, anatomy and medicine, for instance, as subjects much nearer at hand than star-lore. I am inclined to think that the Chaldean shepherds have been overworked, that their contemplation of the nocturnal skies may have been a secondary rather than a primary concern with them. Is it not possible that we owe as much to the hardy venturers upon uncharted seas, whose course could be set only by the sun and stars, when familiar landmarks of the coast had disappeared from view?

But, whatever the cause, the fact remains that the early philosophy concerned itself with astronomy to a degree which, even an astronomer may admit, was disproportionate to the benefits it was conferring upon humanity. Thales, among the earliest of the Greek philosophers, was seeking for fundamentals and speculating on causes. Both the unchangeable character of the starry skies, and, contrariwise, the variations in them, caused by time and seasons, stimulated speculation. Pythagoras perhaps anticipated by centuries the later knowledge of the rotation and revolution of the earth. With a singular detachment of mind from the immediately practical problems, the ultimate origins and causes were sought. Thus the culture of those ages was deeply impressed by astronomy, as interpreted by the philosophers of each period. With the advent of Hipparchus, the greatest astronomer of antiquity, in the second century before Christ, there was introduced the sound principle of basing the science upon observations, rather than upon general ideas of a speculative nature. How hard his successors have found it to follow in that simple but severe test of theory by fact!

The dignity thus given to our subject by its occupying the attention of some of the strongest intellects of the successive ages was further maintained by the favor with which it was regarded by temporal rulers, by princes of secular and ecclesiastical rank. It is obvious that a clear thinker like Julius Caesar did not have an astronomer near him for reasons of superstition, for astrological interpretations, but because he needed his services in reforming the calendar. In the ninth century, A.D., we find the Caliph of Bagdad, Al-Mamon, son of Haroun el Raschid, preserving to the world the works of Aristotle, Euclid and Ptolemy by causing their

translation into Arabic; inaugurating a geodetic survey in Mesopotamia; and founding an active observatory at Bagdad. Albategnius, a prince of Syria, ruler of Damascus, of slightly later date, was a zealous observer, a skilled computer, and introduced improvements in trigonometric methods. Three hundred years later the Mongolian prince, Ilek Khan, founded an observatory in Persia, in which useful observations of the planets were made and the positions of the stars were catalogued. Simultaneously, in Spain, Alfonso X, King of Castile, is furthering the advancement of astronomy, and causes the construction of the so-called Alphonsine tables of the planetary motions. In the fifteenth century, it is a Tartar prince and grandson of Tamerlane, Ulugh Begh, who, a skilled observer, erects a splendidly equipped observatory at Samarcand and catalogues the stars after the lapse of nearly sixteen centuries since Hipparchus. It is perfectly clear that this distinction and interest accorded to astronomy by men of such political and social rank must have greatly tended to the development of public interest in science, with a consequent general culture of the people of the times.

With the advent of Copernicus, (1473-1543), what an immense expansion of mind was prepared for the intellectual world by the substitution of the true heliocentric system for the complicated makeshifts of Ptolemy! Not until after his death did his views receive much attention, but the opposition they aroused in clerical quarters doubless greatly helped to diffuse them. And now came the great explorations of Columbus and his fellow pioneers on trackless oceans. Indeed, astronomy had largely contributed to the general culture of the times, to the grand awakening, the renaissance. Evidence was accumulating to show that comparatively simple laws were governing the complex motions of planets. The careful observations by Tycho and the great generalizations of Kepler were in the logical order of the day. Consider the expansion of ideas, the increase of general culture, which followed the discoveries made by Galileo, as soon as he pointed his perfected telescope toward the moon, the sun, and planets; the existence on the moon of mountains and topography of the general sort of that of the earth; the spots on the ecclesiastically immaculate sun, its rotation on its axis in twenty-five days; the moons of Jupiter and their rapid revolution; the mysterious appendage of Saturn not at first discerned as a ring.

These discoveries, which were merely waiting for the optical power necessary for their revelation, profoundly affected the mental attitude of the intellectual people of the times, when the new knowledge had been diffused. A new place was given to the planets, in their relation to the earth, and a less exalted status in the solar system was the logical consequence for the earth. With its increased, but uncoördinated knowledge, science was awaiting its Newton; but it was almost reluctantly that he gave from his store of knowledge, and we must not forget the great credit due to Edmund Halley for persuading Newton to present the principles he had formulated to the Royal Society. Not only this, but Halley undertook the publication, finally at his own expense (when the coffers of the Royal Society were found to have been drained by other undertakings) of the immortal *Principia* of Newton.

The great impetus thus given to mathematical research, fostered in many cases by monarchs whose other contributions to the uplift of humanity were few, brought brilliant results, and gave the means and methods which led to such a great generalization as that of La Place. We must not forget the earlier and independent philosophizing of Wright of Durham, and of Immanuel Kant of Königsberg. La Place, however, had the mathematical skill and genius to establish many of his conclusions upon a rigid foundation of demonstration. But, in many respects, the generalization of the Nebular Hypothesis outreached observations and mathematical proof. His mind appears to have leaped over barriers which might soberly have been regarded as unsurmountable. He had probably himself hardly seen a spiral, or even a ring nebula. It was beyond the reach of the imagination that men would some day know the chemical constitution of the sun, still less that of the vastly more distant stars and nebulae. But of course the researches of Messier (Louis Fifteenth's "Ferret of Comets") and the splendid investigations of William Herschel, who in 1786 gave to the Royal Society his great catalogue of 1000 nebulae, were available to La Place.

Five years before the publication of the *Systeme du Monde,* which is dated 1796, Herschel, in 1791, had propounded the view that the nebulae differed in nature from the stars. Upon this view he founded his theory of stellar evolution. It has a familiar sound to us now, quite in line with the expanding thought of the last half century. His development of the idea was apparently

quite independent of the theory of La Place, which was published between successive papers of Herschel. He early registered his view that the self-luminous matter of the nebulae was "more fit to produce a star by its condensation than to depend on the star for its existence." He arranged in an orderly series the different objects he had discovered and found "perhaps not so much difference as would be in an annual description of the human figure, were it given from the birth of a child till he comes to be a man in his prime." This reference to the evolution theory of Herschel is made here as a matter of justice; but he is far better known by his many observational discoveries than by his speculation, while La Place is doubtless better known for his Nebular Hypothesis than for his splendid work, the *Mecanique Celeste*.

The impress of the hypothesis of La Place upon the culture of the nineteenth century has been profound. What collegian has escaped the grandeur of the conception of so complicated a result as our solar system developing under comparatively simple laws? To have this conception brought distinctly to the attention of the student is, to my thinking, almost argument enough for making astronomy a required study in college.

Here let me answer in advance the question often asked of the practical astronomer or astrophysicist: Is the hypothesis of La Place now obsolete, and discarded, or supplanted by views better in accord with modern research? My answer would be in the negative, and I know that this view is shared by many of my friends whose opinion I value. It is true that this theory of La Place is inadequate in some respects, and is mathematically unfounded in some particulars. Its premises need modification, and it also leaves much unexplained. But no adequate substitute has been proposed, and the increased study of the different phases of development, as inferred from stellar spectra, supports the La Placean theory surprisingly.

Let us pass to another of the great scientific discoveries of the nineteenth century, crystallizing in the decade when *The Origin of Species* appeared. I refer to the interpretation of celestial spectra. From the beginning of the century, the existence of dark lines in the solar spectrum had been known, and as early as 1817 Fraunhofer had examined with the prism the light from some of the stars and planets. The double dark line in the solar spectrum (known as D) was known to coincide closely with the bright line

in the spectrum of the sodium flame. Stokes, Balfour, Stewart, Foucault, had all groped near to the truth. It was Kirchhoff, whose researches were made in connection with the eminent chemist, Robert Bunsen, who announced in a communication to the Berlin Academy of Sciences, in 1859, the correct interpretation of the dark lines in the spectrum of sun or star: they show the presence of an envelope of glowing vapors around the star.

Here, again, a tremendous expansion was instantly given to the horizon of thinking people. But to astronomers it was undoubtedly a far more impressive discovery, for it was the key to open the door to indefinite new realms of knowledge. Hereafter the position of a heavenly body and its motions were not to be the sole objects of inquiry, but their physical and chemical nature were to be investigated. And one of the special features of the discovery was that the spectroscope suffered no limitations from distance: provided the light was bright enough for analysis, the most distant star could be as well investigated as the nearest. This is of immense advantage, for in practically all investigations which depend upon angular motion (across the face of the sky) the errors of a determination increase proportionately with the distance from the earth.

A wide field for research was opened up by this discovery, and the branch of astronomy known as astrophysics began its remarkable development. The spectroscopic study of all celestial objects was promptly undertaken: in 1864 Dr. William Huggins examined the spectra of a nebula, the bright planetary nebula in Draco. To his surprise, he saw no band of color, the radiation was chiefly monochromatic; the nebula was gaseous. The statement sounds so simple that we lose its immense significance: Here was the first verification of the visions of Herschel and of La Place: they could have had no thought that it would ever be possible to determine the physical state and chemical constitution of the nebulae: even the discoverer, Dr. Huggins, was at the time surprised—he had not suspected the simple result. This was one of the many pioneer discoveries of this fine modern example of a genuine old master of his science, the grand old man of astrophysics, whose death last month, at the age of eighty-six, in the fullness of his mental powers, is lamented by all astronomers. By this particular discovery he showed not only that the nebula was gaseous, but also that it contained the omnipresent hydrogen, in addition

to an element for which a corresponding line has not yet been found on earth, and for which element the name nebulum has been adopted.

With the name of Huggins are associated many of the revelations of the spectroscope, made during more than four decades. Zöllner, Secchi, Lockyer, Janssen, Young, and Langley were among his most distinguished contemporaries in astrophysics, and had a worthy share in the rapid progress then making.

Without here discussing the relative value or amount of the contributions of these leaders, we may say that with the name of Huggins will always be connected the correct theory of the visibility of solar prominences, the first application of the principle of Doppler and Fizeau to the measurement with the spectroscope of the speed of the stars in the line of sight, and the successful development of the photography of stellar and nebular spectra. His discussion of the different types of spectra and of their probable order in celestial evolution is characterized by a sane judgment and clear exposition. It is a duty as well as a pleasure to refer publicly to the debt which astrophysicists owe to our deceased master.

This brings us to another of the great principles revealed by the continued celestial application of the spectroscope and spectrograph, namely, that of the qualitative unity of the universe. Such ideas as this, when properly impressed in the literature of science, cannot fail to affect markedly our conception of the universe, and our relation to it, and thus to contribute to the world's culture. I cannot feel that the idea has ever been sufficiently emphasized in popular writings or teachings. In essence, it is this: Despite the immense quantitative range in the universe, from the infinitesimal to the almost infinitely large, in mass, in space, and in time; qualitatively the range is very narrow, and our sun, our earth, our very bodies, very fairly represent the whole range of quality in the universe. The chemical elements with which we are familiar, which form the basis of our experience on earth, or are spectroscopically obvious in the sun, are essentially the same in the most distant star.

In a universe whose spatial depths are not sounded even by thousands of millions of millions of miles, populated by millions, (perhaps thousands of millions) of vast objects, why should there not be thousands or millions of kinds of matter—chemical ele-

ments by the millions? I see no answer but the fact that there are not, so far as terrestrial or celestial chemistry can yet ascertain. In a century's progress in chemistry, the number of elements detected and differentiated is less than one hundred; and the outlook, as I, without any technical knowledge, understand it, is toward a decrease rather than an increase of the number of elements. And it is just those very elements with which we are most closely associated in our bodies and in our surroundings that particularly abound in the far reaches of space: hydrogen is present, less than half a dozen stars excepted, in every star and gaseous nebula in the heavens; oxygen, nitrogen, silicon, carbon, magnesium, sodium—the most familiar elements of our atmosphere and the earth's crust—are conspicuous in the spectra of stars, both early and late in the course of stellar evolution. Helium, so recently discovered in the earth, after being known to astronomers as present in the sun for the quarter of a century previously, also plays an especially important part in the chemistry of one of the most interesting types of stars, being the chief characteristic of the stars of the *Orion* type. There is one form of hydrogen which chemists have not yet produced in the laboratory, although the keen analysis of Professor E. C. Pickering established its existence in a few special stars a decade ago. Nebulum, too, will presumably be found within the earth, perhaps occluded in some crystals yet to be found into which it may have been absorbed (like helium) ages ago.

This consideration of the homogeneity of the universe offers us some genuine consolation, when we have been depressed by reflections on the immensity of the universe and the utter insignificance of our earth, or our solar system. We may proudly remember that, nevertheless, in quality, which is perhaps a far more essential matter, we share in the choicest of the whole universe. It is a tempting speculation to infer that, if matter does not differ widely in quality in the universe, mind, too, in its relation to matter, is not subject to an extensive range. No logical person can believe that the conditions for the mutual existence of mind and matter solely exist on this particular planet of this particular star, which we call the sun. Hence we could guess that the sentient beings on other spheres of space would not differ so utterly from ourselves. But such speculations can scarcely ever be subject to the test of experiment or observation, and may not be soberly pursued further.

The eminent evolutionist, Alfred Russel Wallace, a contemporary and friend of Darwin, and justly entitled to share with him in the credit for introducing into science the great principle of evolution, has recently, in his old age, written a book, entitled *Man's Place in the Universe*. Basing his discussion upon the premise that our sun is near the center of the Milky Way, he argues at great length and with much erudition (particularly for a biologist essaying in a new field) that the earth is the only habitable planet of this or any system, and "that the nearly central position of our sun is probably a permanent one and has been specially favorable, perhaps absolutely essential, to life development on the earth." The book seems a singular contradiction to the previous work of its distinguished author; in politics it would be called "reactionary." Even if his evidence and arguments were convincing, which they are not to practical astronomers, his conclusions would be narrowing and restrictive. It appears to me a splendid thought that, with our feeble intellects bound down to frail bodies, on a pitiful little planet of a mediocre star, our humanity is able to accomplish so much, see so far, and dream such great dreams. We may share with Dr. Wallace in his appreciation of the following lines from Tennyson, but without excluding from our philosophy the possible coexistence of millions of other abodes of mind and matter.

The Question

Will my tiny spark of being
    Wholly vanish in your deeps and heights?
Must my day be dark by reason,
    O ye Heavens, of your boundless nights,
Rush of Suns and roll of systems,
    And your fiery clash of meteorites?

The Answer

"Spirit, nearing yon dark portal
    At the limit of thy human state,
Fear not thou the hidden purpose
    Of that Power which alone is great,
Nor the myriad world, His shadow,
    Nor the silent Opener of the Gate."

It is characteristic of the audacity of the human mind that it can pause nowhere in a research once begun; finality is never reached; but new avenues of approach toward an apparent solution are constantly opening.

During the few hours I have spent at this University, I have noted, and with satisfaction, the distinctly religious tone of the institution. Let no one fear any ill effect upon a reverential mind from the pursuit of the science that reaches out to the very frontiers of the Universe. The study of astronomy is foremost in demanding the recognition of a Creator greater than all of His vast creation.

The battleground of modern practical astronomy is shifting, out to the problem of the structure of the sidereal universe. The first Herschel attacked the problem, and by his observations laid a foundation for later work. The question of great interest now is, Whither? The genius of the eminent Dutch astronomer, Kapteyn, has detected law in the apparently random residual motions of the fixed stars. Dealing with stars, not singly but in great groups, he has found evidences of what he has called "star streaming." The study began with the determination of the sun's way, the path along which the sun is hurrying, carrying with him his unconscious planets, toward the region between the constellations Hercules and Lyra. Other astronomers confirm the conclusions of Kapteyn that there are in the sidereal universe at least two great streams of stars, and that they cross each other and mingle at some points. Such a problem is so vast, and the data required are so extensive, that it transcends the capacity of the astronomers of one country. Like many other large practical problems, as for instance the great star catalogue of the *Astronomischen Gesellschaft*, or the great photographic chart and catalogue of the whole heavens, such undertakings have to be international. Conferences, charming in their generous hospitality and fraternal courtesy, are now being often held in different countries. The International Solar Union, for the coöperative study of the sun and its phenomena, meets this year at Pasadena. Such gatherings, becoming frequent in many other branches of science and art, are quietly but powerfully contributing to the cause of international peace. Continued and developed, they will operate effectively against the crowning absurdity of our age, the huge armaments of the great powers. If the productive power of the men thus withdrawn from useful activity could be utilized, and the vast sums of money wasted on unnecessary ships could be spent on submerged humanity, how immense would be the gain to civilization!

In celebrating to-day the opening of the beautiful observatory which will hereafter develop in this institution the science which has been my theme, it is fitting that we should briefly consider the advantages to student and teacher of the study of astronomy, both general and practical. The eminent classical authority, Professor Mahaffy, once told me that at Trinity College, Dublin, there were but two required subjects in the curriculum: logic and astronomy; and he justified this choice. It is surely true that no other subject of college instruction so instantly or so greatly broadens the horizon of the pupil. It is likely to catch the imagination and interest as few other topics do, and particularly when an observatory is at hand, where celestial objects and their phenomena may be demonstrated to all the members of a class. The vision of the planet Saturn or of a fine star cluster, in a good telescope, is likely to produce an impression that time will hardly efface. As a foundation for geology, geography and meteorology, and as affording constant applications of principles previously learned in mathematics, physics and chemistry, astronomy has a particularly important place in the college curriculum. Mere familiarity with the principal constellations, once acquired in connection with a course in astronomy, will always prove a pleasure to its possessor, perhaps increasingly so in later life. The understanding of the general facts of planetary motion, as of the changes from evening to morning star, is also likely to be a permanent source of satisfaction.

The pursuit of courses of practical astronomy in an observatory is essential to the education of an engineer, and very desirable for those specializing in the physical sciences. The art of determining the time and the observer's position on earth from observations of the stars, gives the student who acquires it a certain self-reliance that is of lasting value to him. The accuracy necessary in all computations involved in the reduction of his observations gives an exceptionally good drill in applied mathematics. The principle that no observation made by the human eye is absolutely precise, and that no instrument is ever in perfect adjustment, and that these errors must be determined and allowed for—this principle is of obvious use in the training of any student for precision in any future work.

Courses or studies in astrophysics, such as observing, measuring and following the motions and changes of sun-spots, examining

ERAS	PERIODS
Cenozoic	Present
	Pleistocene
	Pliocene
	Miocene
	Oligocene
	Eocene
Mesozoic	Cretaceous (Upper Cretaceous)
	Comanchean (Lower Cretaceous)
	Jurassic
	Triassic
Paleozoic	Permian
	Pennsylvanian
	Mississippian
	Devonian
	Silurian
	Ordovician
	Cambrian
Proterozoic	Keweenawan
	Upper Huronian (or Animikean)
	Middle Huronian
	Lower Huronian
Archeozoic	Archean

The consolidated rocks of Ohio belong entirely to the Paleozoic era; resting upon these, is much unconsolidated rock material belonging to the Pleistocene and Present periods of the Cenozoic era. We have, then, no rocks that are geologically very old, nor have we the hard and resistant rocks. The formations of the earlier periods have undergone changes that make them less easily disintegrated by agencies of weathering; they are uniformly more dense than younger rocks. The formations of the early eras are usually crystalline in structure, whereas sedimentary rocks characterize the later eras. It is not improbable that many of the crystalline rocks were originally sedimentary.

River sediments. Since the rocks of Ohio are sedimentary, it follows that they had their origin in the assembling of the weathered products of older rocks. The rivers that to-day carry off the products of weathering are depositing these products along their courses and in the oceans; such deposits will in time form sedimentary rocks.

Where were the land areas whose streams bore the sediments from which were built the series of rocks within this state? Obviously much of the sedimentary rock material of Ohio was transported here by drainage from older lands to the north, while some may have been deposited by streams flowing westward from lands that existed farther east. While the rocks of our state were accumulating, the ocean occupied the region of the present Mississippi valley; the Ohio area, during most of the time, was a portion of this interior sea, but later it was a gulf or bay extending northeastward.

The same agencies were active in forming the sedimentary rocks in the Ohio scale as are in operation at the present time. Along the rivers material is in transit. Some of this load is always on the move; some is carried on in installments, a period of rest following one of movement. The part of the load that reaches the large bodies of water, a lake or the ocean, is the finest; this is largely deposited near the mouth of the river as a delta. In time the delta grows more and more into the body of water, forming a wider marsh region. But a very significant part of stream deposits is found in the flood plain that borders the river channel from the sea inland; in the flood plain of any mature river we can see ample deposits, enough to make hundreds of deltas such as exist at the river's mouth. As the major river widens its valley, the tributaries also become bordered by deep deposits which they are unable to carry onward.

So a river's history is one of constant work, and of various kinds of work. At some particular point along the river's course, it is doing such work as at an earlier time it did farther down stream. Rivers first cut into the rock, deeper and deeper; later they cut laterally, making the valley wider. But while they are engaged down stream in widening a valley, upstream their business is deepening the valley. So long as the stream is cutting deeper, it generally carries away the products of this erosion; when the work changes to valley-widening, it fails to carry off all of the products of its erosion; thus flood plains are made.

An old valley need not be of great length in order to have several hundred square miles of flood plain deposits; the Mississippi southward from Cairo, Illinois, is an example. A large percentage of the surface of a region that contains several old streams consists of flood plains. Much of this flood plain material in a later

period is changed to consolidated rock without ever being carried to the seas. There was a time when students thought the sedimentary rocks all represented material that had been deposited in, or near, the oceans.

Ocean sediments. On the other hand, ocean waves and currents are contemporaneously engaged in eroding the rock along parts of their borders, and in further refining the river deposits. Thus the oceans may be constantly sawing into the continents, pushing their cliffs gradually inland, thus contributing materials for sedimentary rocks of the future. The waves undercut the cliffs, pound up and prepare a load which the ocean currents carry away, assort, and deposit. Our seashores then are another belt where sedimentary rocks are in-the-making. Nevertheless a conspicuous part of the sedimentary rocks are associated directly with river basins.

But how may we so distinguish the rocks of the past that we may be sure which of them represent old seashores and which flood plains? It is not an impossible task. Careful study has been made of the prolific life of the ocean border tract, and the sometimes equally abundant life of the river flood plains. These faunas in the main are quite distinct: on the one hand marine, on the other, fresh water. When the animal dies its tissue is sometimes replaced by minerals, producing a fossil. In the fossil form these organisms may be studied and classified. Therefore it is usually possible to tell whether a certain horizon of rock represents fresh water or marine sedimentation.

THE ORIGIN OF ROCKS

Old ideas as to the origin of rocks have been somewhat modified in recent years, because of new teachings of astronomers and physicists in reference to the origin of the earth itself. There are two more widely accepted hypotheses of earth-origin. I will state briefly the parts of each which bear more directly on the genesis of rocks.

Nebular Hypothesis. The early conception of our globe pictured its gradual evolution from a spheroid of gas which slowly condensed, acquiring great heat, and forming at last a molten body about the size of the present earth. As heat was radiated from the surface of this hot spheroid, a cool crust developed;

with the radiation of further heat, this crust shriveled about the contracting center. In this manner mountains were made. Later, with the appearance of an atmosphere and hydrosphere, the agents of weathering with which we are acquainted became operative.

Since the earliest rocks formed were considered frozen or cooled molten material, they were called plutonic rocks. So the basal formations, according to this theory, were looked upon as igneous; and the later weathering of the igneous rocks produced material that formed the sedimentary horizons. This is the Nebular theory of earth-origin, omitting, of course, all details that concern the origin of other members of our planetary system.[1]

Astronomers of the present generation have made wonderful discoveries; their predecessors had neither such powerful telescopes, nor the other observatory equipment with which the modern astronomer does his work. The marvelous facts of the heavens revealed by the great observatories in recent times have caused doubts concerning the time-honored Nebular hypothesis, which had its origin in very incomplete data at a time when observations and calculations could not be accurately made.

Planetesimal hypothesis. Quite opposed to this, is a theory which has been formulated within the last decade. In accordance with this hypothesis our earth has not always been a contracting body; it was not a molten mass to start with, but instead a gradually increasing sphere possessing a moderate degree of heat. This theory conceives our planetary system as having evolved from a nebulous body like the present nebulas, the units of which are called planetesimals. The large modern telescopes show the prevailing form of nebula to be disc-like, not spheroidal, in outline, and to be spiral in structure; to have a denser center from which generally two arms extend giving the nebula its spiral structure, and to have apparent motion about this center; furthermore, there appear dense masses or nuclei along the arms, and in the interval between the nuclei, as well as between the arms, "finely divided and nebulous material."

In their revolution about the center, it has been suggested, the orbits cross and collisions between planetesimals take place,

[1]For a full discussion, see Moulton's *Introduction to Astronomy*, pp. 440-447, 1907.

forming larger particles. The orbits of single and combined planetesimals cross or pass near the orbits of nuclei, whereupon the smaller bodies unite with the larger. By this accretion process bodies are formed which dominate a certain amount of space from their centers. These growing masses through further accretions became initial planets. Some of these may unite with others, but eventually the members of our present solar system were formed.

But we are concerned with neither hypothesis any further than the aid it offers in understanding the origin of rocks; both accord in the principle that sedimentary rocks contain the weathered products of older rocks.

Age of weathering processes. The Nebular hypothesis, however, gives us only a limited zone of secondary rocks, while the Planetesimal teaches that secondary rocks were in process of formation from a time when the earth was but a fraction of its present size. In the various processes of weathering, water and certain chemicals are the essential factors. But there was a time, it is thought, when the earth was not surrounded by an atmosphere, and its surface bore no hydrosphere. In the absence, then, of these two spheres, it is probable that the original rock suffered very little change, certainly not all the changes which we know of as weathering. An atmosphere is matter in the gaseous form. Only when a planet becomes large enough to exert sufficient gravity to hold gaseous matter near its surface, will it have an atmosphere; for this reason, the early atmosphere of a growing planet consists of the heavier gases.

The moon has no atmosphere; hence we believe that the gravitative power of the moon is not sufficient to control hydrogen, oxygen and other gases. We are also told that Mars, which is about one-tenth the size of our earth, has a very slight atmosphere. From this fact we infer that Mars is large enough to control some gases. If the analogy of these two members of our solar system may be used in interpreting the theoretical history of the earth, it must be concluded that the earth has been surrounded with at least a slight atmosphere from the time it was about one-tenth its present size. The surface of the moon appears not to have a hydrosphere. Whether Mars has any water on its surface, is a mooted point. Theoretically, however, we would infer that a growing planet should have a gaseous envelope before the de-

pressions on its surface would be filled with water. If water appears before the atmosphere, we might thus account for an atmosphere, because hydrogen and oxygen in the water molecules are readily vaporized, and should, if present, give the growing planet a gaseous envelope in the form of vapor.

Accepting the teachings of the Planetesimal hypothesis, it is safe to conclude that the agents of weathering have been operating on this planet at least from the time it was much less than one-half its present size. The earth was growing apace, through accessions of unattached bodies from the original nebulous matter. Thus during the time that the globe has been making at least half its growth there has been a mingling of new material from without and the weathered products of old material. But the amount of the accessions has progressively decreased; since the beginning of what is generally called "geologic time," the Archeozoic era, the accretions are relatively negligible. Nevertheless every meteorite that occasionally falls adds something to the earth's mass.

Weathering is the agent that rends old rocks and produces new ones. Freezing effects, the expansion of higher temperatures, and certain chemical changes cause disintegration; stream and wind erosion, and later transportation of the weathered products to lower altitudes and into water bodies are details in the change from original to secondary rocks.

First stage in rock-making. You have seen cemented masses of clay, gravel, large and small stones, and possibly also organic material, which had been bound together by a deposit of carbonates, of iron, or of silica, precipitated from ground waters seeping through the masses? This is an early step in the development of sedimentary rocks. In accordance with the coarseness of the material thus cemented, the rock produced is termed a conglomerate, a sandstone, or a shale. Later other sediments may be deposited on top, the weight of which tends to further indurate the lower sediments. Pressure also arises from the movements of uplift and depression incident to the development of land areas. These movements are sometimes extensive, folding the rocks, or even stretching them throughout large areas. Such mechanical action produces heat which is considered a very active agent in altering rocks. Thus, an original mass of loose sand, or of coarse and fine gravel, in time will become a sandstone or a

conglomerate, and under further action of the same agents may later be changed to rocks that are quite unlike the original.

Metamorphism. Geologic time is involved in these processes. The time units of human beings give us but a slight conception of geologic time. The process that changes rocks into quite different rocks is called metamorphism. Metamorphism, it is thought, has altered all rocks appreciably, save those of the most recent period of earth-history. Metamorphic agencies have been so effective in changing some rocks that it is very difficult to tell what may have been their original form.

When we recall that man sees only the upper part of the earth's rocks, never getting a view of more than a few miles below the surface even when he combines numerous outcrops widely separated, we begin to comprehend the limitations in his study of rocks. These limitations have led to his setting up standards of earth-history, implying an equally short period during which the agents that have produced secondary rocks have been operating. His not comprehending the extent of metamorphism has also led to his interpreting the older crystalline rocks as primitive or "plutonic." According to later views many rocks of the Archeozoic may be altered sedimentary strata.

The effects of metamorphism are variable. Sometimes a familiar rock blends into its metamorphosed product. For example, marble, which is an altered limestone, may be quarried in a locality, on either side of which, within a distance of a few miles, the marble gives place to limestone. Again, an outcrop of quartzite, traced laterally, may blend into unaltered sandstone.

That heat is an important factor in metamorphism, we are certain, because near the line of contact between a dike of igneous rock and the formation it cuts, the strata are changed, whereas a short distance from the contact, they are unaltered. A flow of lava coming in contact with a bed of bituminous coal may change it to anthracite. Many other illustrations might be cited, showing the effects of heat, pressure, water, and chemical agencies in altering rock.

Clastic and organic rocks. The sedimentary rocks formed by assembling worn out products of older rocks are called *clastic.* The great bulk of our secondary strata belong to this division. Not all the load which rivers carry from the higher areas to their flood plains and into the ocean is deposited, and later turned into

secondary rock. Many of the constituents of older strata are broken up into their chemical elements, and as such enter the oceans. Because of this fact, ocean water is salty and heavier than fresh water. We sometimes speak of the saltiness of the sea, usually referring to sodium chlorid. But this is a single chemical; all the list of chemicals found in rocks exists in sea water. Certain animals in the oceans feed upon particular chemicals. The carbonates, and to some extent the silicates, are converted into the hard parts of sea organisms. When these organisms die, their shells, spines, etc., are assembled at the bottom, and when especially numerous make characteristic deposits; becoming rock, these are named in accordance with their prevailing constituent. If the animal's remains consist largely of carbonates, the resulting rock is called a limestone; if the clayey or sandy content is conspicuous, it may be called a calcareous shale or sandstone. In the deeper parts of the seas, however, smaller organisms exist, and their remains become a part of the ooze that mantles the bottom of the ocean basins. Rocks which are built up largely of the decayed products of life are called *organic*.

Rocks precipitated from solution. Sometimes the percentage of a given chemical becomes so high in water that it is precipitated, depositing on the bottom of the basin that particular salt. It may be a gypsum deposit, a sodium chlorid deposit, or some carbonate. This process of direct precipitation is usually associated with arid conditions in an inland drainage basin. Here the evaporation is greater than the rainfall; as a result, the amount of chemicals in the water is constantly increasing. When, for a particular compound, the saturation point is reached, it is precipitated. Later the solution may become saturated for another compound, which in turn is deposited.

The remarkable salt deposits in Ohio belong to this class of rocks. Their genesis, however, may not be associated with inland drainage; this question is discussed in an earlier section (p. 152).

THE GROWTH OF LAND AREAS

The geologic scale of Ohio includes clastic, organic, and chemical rocks. We have no crystallines, and no metamorphosed rocks in place; but scattered over the surface throughout at least half of the state are found bowlders of crystalline and metamorphosed material brought from Canada by the glaciers.

For many miles off the eastern coast of the southern Atlantic States the ocean is very shallow. A relatively slight upward movement of this part of the continent, or a corresponding withdrawal of the ocean, would add to the area of North America. This added belt would be called a "coastal plain." Continents often grow thus, taking from the shallower parts of the oceans.

The Cincinnati arch. Towards the close of the Paleozoic era the sea withdrew finally from the region of Ohio. Before that time, only a small part of the state's area was above sea-level; in the southwestern corner, about Cincinnati, is the oldest land in Ohio. Long before the close of the Paleozoic era, a dynamic movement gradually produced an arch, raising from the surrounding sea a long peninsula-like strip. This has been termed by students the "Cincinnati arch," and it is very typical of the orographic movements associated with the growth of continents.

Just why certain areas near the continent borders are moved differentially, or bent into arches, is not clear. Some hold that it is due to the unequal distribution of sediment from the contiguous lands. If the products of disintegration were evenly spread into the oceans, it is urged, we would not have the irregular oscillations, but where a narrow tract is thus overloaded the rocks beneath are compressed accordingly and an arching of neighboring rocks is produced. When two such overloaded areas are not far apart, the intervening belt may be bent upward, as illustrated in the Cincinnati area.

Students determine the approximate time when such a movement occurred by a study of the rocks involved. In the case at hand the disturbed rocks show a maximum movement near the southwest corner of the state, only diminishing northward; one effect of this arching and the resultant stream erosion may be seen today in the scattered limestone islands about Sandusky. The strata dip downward on either side of the axis of this uplift. Along the axis the older rocks are found nearer the surface. Furthermore, along this axis weathering and stream erosion have been most active; also the last sediments deposited before the movement began are uppermost, and dip either way from the axis. Since along the borders of this arched area, the rocks are much younger than any found on its top, it is inferred that the arching commenced before these younger sediments were depos-

ited. Accordingly, the beginning of the uplift movement has been definitely associated with the latter part of the Ordovician period.

Appalachian mountain-making movement. For a long time after the development of the Cincinnati arch, the Ohio region was almost continuously a part of the sea. In addition to the arched area, lands exposed to weathering existed to the north, and farther away to the east. From these sources, products of weathering were being transported, gradually making more and more shallow the sea over this region. The great dynamic movement that produced the Appalachian mountains commenced in the Permian, the closing period of the Paleozoic era. This folding probably began in the eastern section of the northern Appalachians, proceeding westward and southward. The youngest sediments found in Ohio belong to the Permian. It is possible that sedimentation may have continued after that period in parts of our area; if so, such deposits have been completely removed, or have never been located by geologists.

Since the Permian, then, the normal agents of weathering, which we see all about us to-day, have been acting on the rocks of our state, sometimes subdued, at others vigorous. At intervals the rivers have been building flood plains, as their velocities lessened; again, because of a differential movement, or because of an uplift, the invigorated streams commenced to erode their beds and carry away waste products. Later, all these processes were checked in about half the area of Ohio by a sheet of ice (p. 185).

The Allegheny plateau. The western slope of the Allegheny plateau extends diagonally across the state from northeast to southwest. This plateau, ranging in altitude up to thirteen or fourteen hundred feet, is genetically associated with the same movement that produced the Appalachian mountains. The Ohio river and its tributaries have in a measure severed this part of the uplifted region from the more elevated section to the east; the Scioto, of its several tributaries, occupies the greatest gap in the plateau. Not only is this section elevated, but closer study of the rock structures betrays many folds and flexures also, consisting of slight anticlines and synclines. The rocks concerned have a prevailing dip to the south and east. They consist of clastic sediments in the main, mostly sandstone and conglomerates;

some horizons are more or less clayey, others are quite calcareous. The alternation of hard and soft horizons of rock is a factor in the irregular topography that characterizes the Allegheny plateau through part of Ohio.

Relief and glaciation. But the irregular relief of this area is the result of long continued weathering. The agents of erosion have acted intermittently. Several drainage cycles have been concerned; one at least is thought to have worked itself to completion, or to base-level; the rest were checked at different stages. The result is the complex physiography, manifest particularly in irregular drainage, which is due chiefly to stream divergence and capture, a subject discussed more fully in a later section (pp. 389–392).

The superficial deposits covering more than one-half of the state are of glacial origin. This glacial drift is a mantle of weathered rock in varying degrees of comminution. Its origin and the complex processes involved in its transportation are more fully considered in the chapter devoted to glaciation. No phase of the geologic history of Ohio is more important than glaciation, which is the basis of the rich soil that has given the state its rank in agriculture.

GEOLOGIC TIME PERIODS REPRESENTED IN OHIO

The rocks of this state dip gently to the south and east. As a result of this attitude, and of weathering since the sediments were deposited, the older formations outcrop in the northern and western parts of the state, and the youngest in the southeastern section. The rocks of the several periods, therefore, have a surface arrangement somewhat resembling that of shingles on a roof, the ridge board being the axis of the Cincinnati arch.

Formations extending from the Ordovician to the Pleistocene periods outcrop in Ohio. Only by aid of the State Geological Map can the boundaries of these periods be satisfactorily followed, in the description below. This map may be procured of the State Geologist, J. A. Bownocker, Columbus, for twenty-five cents; every teacher in the state should have one at hand.

Ordovician. The rocks of this period are on the surface in the southwest corner of the state. They outcrop along the Ohio river east to the valley of Brush creek, Adams county, and northward along the Great Miami river nearly to Piqua, from which

place the boundary follows an irregular line southward through Xenia, near Wilmington, and thence to the Ohio river. Westward from the Great Miami, the boundary is very irregular, an arm of the Ordovician rocks being exposed northward along each of the more important tributaries of this river, among them the Stillwater and Twin creeks. Within the area thus described are a few patches of rocks belonging to the next later period; these are outliers or erosion remnants; in the southeast part of the region, also, stream cutting, chiefly that of Brush creek, has given the Ordovician rocks an irregular surface distribution.

Silurian. The boundary of the area just described is the lower contact line of the Silurian formations. From this line the Silurian rocks extend to the east and north as far as Lake Erie, and into Michigan. The eastern boundary of the Silurian is quite regular from Sandusky bay south to Ross county; from Ross county to the Ohio river the margin of the outcrop is irregular, a condition due to river work. Omitting the Ordivician area and a region in the northwest part of the state, embraced by Williams, Fulton, Defiance, Henry, and slight portions of adjacent counties, all of the state west of this north-south line belongs to the Silurian. The Bass islands, and all save the eastern end of the peninsula formed by Sandusky bay, are comprised within Silurian territory. In Logan county, east of Bellefontaine, is an area of rock belonging to the next later period; rocks of the same period are on the surface also in Taylor township of Harden county. With these two exceptions, the territory described belongs entirely to the Silurian. For a distance of about ten miles along the Ohio river west of Vanceburg, Kentucky, the Silurian formations outcrop.

Devonian. The chief exposures of the Devonian rocks in Ohio border Lake Erie westward to Sandusky, and occupy a strip about thirty miles wide extending south across the state as far as Chillicothe. From this point to the Ohio river, the boundary of the Devonian outcrop becomes very irregular and decreases in width; it shows along the Ohio river for about twenty miles east of Vanceburg. Along the Scioto valley, southward from Waverly almost to Lucasville, the Devonian is on the surface; the same outcrop continues westward in a narrow band through Pike county. From the western side of Pike county southward through Adams and Scioto counties the rocks of this period have

a very irregular surface distribution. Kelley's island and the eastern end of Marblehead peninsula consist of Devonian formations, as does also the northwest corner of the state, omitting Williams county and a portion of the western end of Fulton county. From Sandusky eastward, the Devonian occupies a narrow strip bordering the lake, narrow as far as the meridian of Unionville, Lake county; east of this meridian, the Devonian outcrop broadens southward into Trumbull county.

Mississippian. In the northwest corner of the state, the Devonian formations border an area comprising all of Williams county and part of Fulton; the rocks of this area are mapped as probably of Mississippian age. The principal area of the Mississippian outcrops extends northward from the Ohio river; this area on the west has a fairly uniform boundary with the Devonian on the west; but on the east, its contact with the later formations is very irregular, the irregularity increasing to the south. The channel of the Ohio river shows Mississippian formations from the Devonian outcrop in southwestern Scioto county eastward to the vicinity of Ironton. Along the east and south-flowing streams, including the Hocking, Licking, Mohican, Killbuck and Cuyahoga rivers, outcrops of the Mississippian reach into the territory of the next later period. East of the Cuyahoga valley the Mississippian formations meet the Devonian in a very regular line of contact, but occupy a relatively narrow surface area as far as the meridian of Unionville; beyond this meridian in Trumbull county, the Mississippian area broadens almost to the north-south width of the county. The valley of the Mahoning cuts into the Mississippian rocks as far east as Youngstown. From Youngstown northward, the contact with the rocks of the next later period is quite irregular.

Pennsylvanian. Nearly all the remainder of the state is occupied by the outcrops of this period; in this area is found the most broken topography of Ohio, and the greatest variation in altitude. The Pennsylvanian rocks approach Lake Erie nearest in Geauga county. The boundaries of the different formations of the Pennsylvanian rocks are extremely irregular. In no portion of the state are the streams more numerous. This active river erosion has produced the irregular distribution of the Pennsylvanian formation.

Permian. The exact distribution of Permian formation has not been worked out in Ohio. Their existence north of the Ohio river has been established, and the State Geological Survey is now engaged in mapping the Permian rocks. For this reason the state map makes no mention of this period.

IN GENERAL ON GEOLOGIC PROCESSES

The tearing down of old rocks and building their products up again into new ones, as above described, is a relatively simple process. But simplicity of action is not general in earth-history. Conditions appear constant only because of our limited period of observation. Perhaps in no other science is there less comprehensiveness than in Geology, not only because much of its data does not admit of close study, but also because this data, to be correctly interpreted, must be observed through periods involving the lives of many generations. It is for this reason, that we have so few geologic activities standardized. The mountains are not stable, nor are the seas confined; the former wear away, the latter deepen and shallow. When there is stability in the one and mobility in the other, the line of contact on which both are measured shifts accordingly. So it may be impossible to say whether a certain change in altitude represents an upward or a downward movement of the land, or an extension or withdrawal of the seas. Either movement on the part of either body introduces the appearance of the opposite movement on the part of the other. If the sea withdraws, the area of the land increases; if the land subsides, the sea appears to be extending. But these shifts which vary altitude are only one manifestation of the inconstancy of our land and water bodies. Instead of being able to interpret these movements as due either to a definite uplift or depression of land, or to the extension or retreat of waters, closer study usually shows that there has been a differential movement, indicated here by a certain rate of uplift or retreat, and there by a different rate. While the full value of these movements in time past may never be accurately estimated, it is, however, a satisfaction to know that the students of later generations will have accumulated data on which more satisfactory conclusions may then be based.

The great difference between geology and other sciences is that it imposes upon us greater patience. Our generation can record observations; another, we know not how far ahead, must make the deductions. Formerly some of the earth's functions were catalogued with the supernatural; now many mythological deities and lesser personages have been resolved into simple and usually harmless natural phenomena. In geology the field of fact has spread quite completely over that of fancy. The catastrophies of the past have become the mild, ever active, forces of the present. Mountain-making, canyon-cutting, lava-extrusion, and earth-tremors, are normal functions of the globe. If rivers flow across mountain ranges, it is because the mountains grew so slowly that the rivers held their courses. If a river has cut down into the rocks much more rapidly than it has cut laterally, it is because the region has been subject to relative uplift, thus keeping the river young.

THE RELIEF FEATURES OF OHIO

FRANK CARNEY

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INTRODUCTION

The smaller islands of the Pacific are usually divided into two classes: high islands and low islands; these are very simple examples of the relationship between geologic structure and surface features. The low islands consist of organic rock, the products of coral making animals, whereas the high islands consist of volcanic products. In an area like Ohio, involving over forty thousand square miles, we find no such simple conditions as exist in these Pacific islands. A pleasing variety of relief characterizes this state: in the northwest are gently sloping plains, and in the southeast a dissected low plateau; the intervening topography blends easily from one into the other.

Composition, structure, and attitude of rocks in relation to relief. Geologic processes and results are basal to relief. Rock character is generally an important element in a landscape. What the rocks of an area are, and what has happened to them since they were deposited, are the first questions to ask in accounting for surface features.

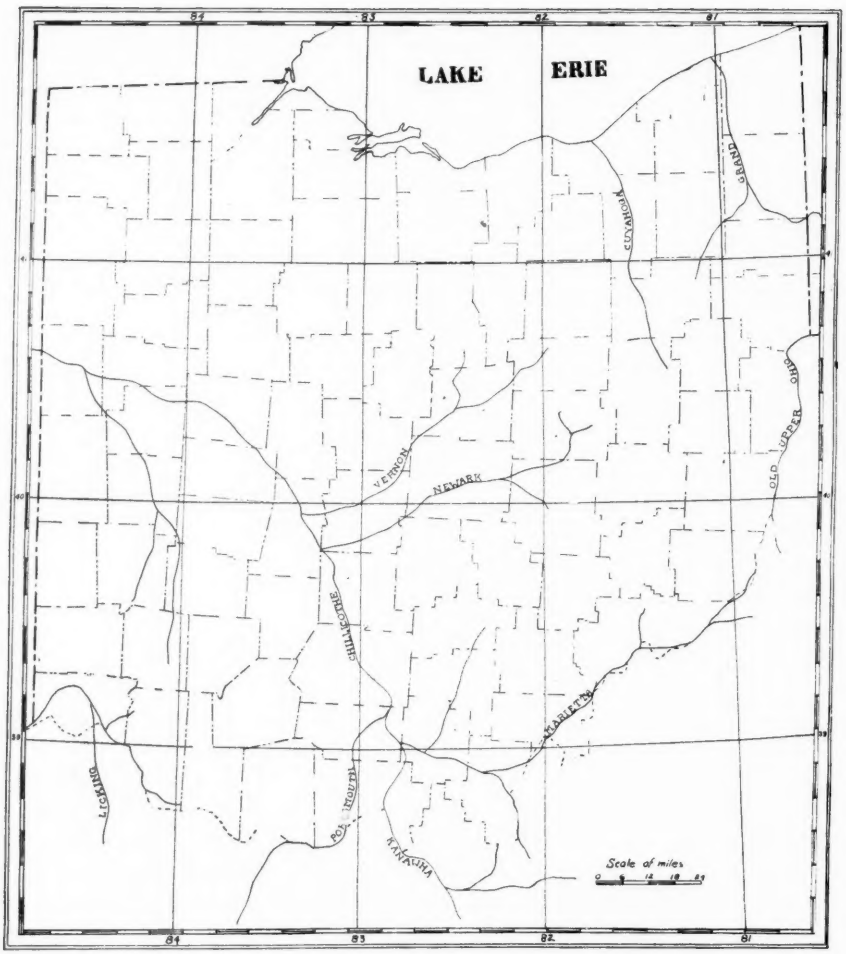

FIG. 1. This map, showing a former drainage pattern of Ohio, is based on the work of Tight, Bownocker, Leverett, Fowke, and others. Since the map combines the findings of several investigators, it may not accord fully with the views of any particular one.

Limestones are soluble, hence are readily affected by surface weathering and ground water. Clastic rocks containing a soluble cement yield rapidly to the same agencies. Formations made up largely of either of these types of rock go to pieces much more quickly than do rocks that contain no soluble constituents.

Sometimes the rock has a simple structure; at other times, complex; the simplest structure is an approximation to the horizontal position, the original attitude of most sedimentary formations; the more complex attitudes are found in mountain areas like the Appalachians and the Swiss Alps; jointing and faulting may introduce further complexity of attitude. When the rocks have been highly folded, some of the formations being harder than others, the structural valleys, and the inequalities resulting from differential weathering, give the country a very irregular surface, as illustrated in parts of Pennsylvania.

Massive beds of rock are more resistant than thin layers. Occasionally, sedimentary beds may be heavy, but massiveness is usually associated with igneous rocks.

Furthermore, if the rocks are loose in texture and are fairly homogeneous throughout the district, the stage of strong relief will not endure long; even when such formations have been folded and faulted, but not to the extent of disclosing rocks which differ much in texture and structure, the result will be the same. When thick hard horizons alternate with less resistant strata, irregular topography prevails much longer; the more resistant a given formation is, the longer it withstands weathering, and stamps itself on the topography; even in the absence of crustal deformation, this arrangement of rocks will give some relief, but when the strata have been folded, the surface irregularity is correspondingly greater. Since in Ohio, omitting an area in the southwestern part of the state, all of our formations have a general dip to the south and east, the relief quite accurately reflects the rock texture and structure.

If one starts from Toledo and crosses the state directly to Parkersburg, W. Va., he passes over the outcropping edges of most of the rock formations in Ohio. The first part of his journey is over limestone horizons; this is followed by a belt in which shale outcrops; thus far, the route covers a region of slight relief, largely because the limestone and shale have weathered uniformly. Next he enters a belt of clastic sediments, consisting chiefly of sandy

shale and sandstone; the more resistant beds produce slightly greater surface irregularity. For some distance after the traveler has passed the center of the state, he finds himself in more hilly country, where coarse sandstone and conglomerate horizons are on the surface. Following this he enters the coal region, where the sandstone and conglomerate beds are heavier and have better withstood the effects of erosion, giving rise to the most irregular topography in the state. Towards the Ohio river, the streams become more numerous, and the relief more mature.

Had this traveler turned southward from Toledo, soon he would have found himself near the axis of the Cincinnati arch where the formations dip in either direction, on his way to Cincinnati; for some distance the relief is mild, and large streams are wanting, but approaching the Ohio river, the limestone has been cut by streams, and greater surface irregularity exists.

Other influences in relief. Thus the rocks have a marked influence on the elements of a landscape. There are, however, some minor factors that tend to vary the relief which rocks would otherwise always produce. Among these agents are glaciation, and variation in stream history. The deposition of glacial drift generally tends to make the surface features more regular; but in some localities ice erosion has very appreciably increased the relief. Crustal movements, orgogenic and epeirogenic, have induced stream capture and divergence, which frequently account for relief features that do not entirely reflect rock structure and attitude. In another place I discuss these factors more fully (pp. 199–202; 388–392).

Physiographic regions of Ohio. Ohio cannot be parceled into distinct physiographic regions. Its surface has pronounced relief features, but these so blend into each other that it would be rather arbitrary to draw lines of division.

Along the Atlantic seaboard the coastal plain is distinctly set off from the Piedmont belt by the Fall Line. This is a clear cut physiographic boundary. Except for a short distance in the vicinity of Cleveland, and east of that city, we have nothing that even simulates this kind of a boundary. The following is a suggested division for the physiographic regions of this state: (1) the lake plain; (2) the plateau area. These divisions are structural in origin. The first reflects to some extent the minor factors in producing relief features, alluded to above. The second division is dependent quite entirely on underground structure.

It would be erroneous to infer that rock structure and attitude alone account for marked relief. To appreciate this fact, we have only to recall certain arid parts of the world, desert plains, where weathering is due mostly to temperature changes; there the landscape is monotonous, almost devoid of relief; the slight irregularities present usually represent wind deposits.

River and valley development give pleasing details to relief features; the beautiful landscapes have been thus produced. Our range of vision from any particular point seldom grasps more than the irregularities of stream erosion. So, while the basal control in physiography is the rock structure, the details that are within our visual grasp depend largely upon stream work.

River history. There are a few terms that we should understand in any discussion of stream work. All apprehend the fact that if the agents of weathering are given time enough in a land area that continues stable, that is, is neither uplifted nor depressed, these agents will bring the area down to the level of the sea; the agents of disintegration will have crumbled the rocks, and streams will have distributed the products. When, in a given region, the streams have accomplished this, that region is said to have been *base-leveled.* A requisite condition, then, for base-leveling, is a static position of the land area. Whenever earth movements tend to uplift or to depress a region, the stream history becomes complicated and the normal process of base-leveling is either checked or accentuated. A particular river in a base-leveled country may be said to have completed a *cycle.*

The river started at the ocean border as a notch in the rim of the land; its course gradually lengthened; tributaries developed on either side whose courses also lengthened, and widening of the basin continued until no more area could be reached. A stream system, with the aid of the weathering agents at work between its several tributaries, in time reduces its basin approximately to sea level. At first it was a *youthful* stream, having a steep gradient and a narrow valley; next it passed through the period of *maturity*; and the last stage of its history was that of *old age.* In river development these three stages constitute a cycle; but you observe at once that for the regular development of the cycle, it is absolutely necessary that a static relationship exist between the land area and sea level. This is a theoretical consideration, the

ideal way of studying the origin of relief features, and it represents a laudable desire to standardize physiographic processes.

Nature, however, is not always so systematic. Oscillation appears to be the habit of boundary lines between the oceans and the lands. It is not known that any land area ever has remained static long enough for the theoretical development of a river cycle. Instead of being able to point out a particular area where the rivers have had this theoretical life history, we can with more success find the three stages existing contemporaneously in one and the same drainage basin. While the headwater parts of a river system may be in youth, the portion near its mouth will bear the earmarks of old age, and maturity will characterize the parts between these limits.

If the diastrophic movements of our continents were spaced by drainage cycle periods, the land surfaces would then have such roughening as would follow from one plain of erosion giving place to the details of another plain of erosion. In that case, the uplands would be peneplained; and beneath this level the new drainage cycle would cut its valleys. What appears to happen more often is that after a cycle has been under way, its development is either retarded or hastened, and drainage irregularities are introduced. These irregularities may result from the advantage taken of weaker stream basins by the more vigorous drainage basins. Thus, when a land-tilt appreciably increases the velocity of one river, it correspondingly retards the current of the river flowing in an opposite direction from the same divide, and, as a result, the former encroaches on the drainage territory of the latter. This is river *piracy*.

While piracy generally follows from land-tilts, as just mentioned, it may also occur when one of two streams, which are balanced, cuts into harder rock, while the other stream continues in the original homogeneous strata. The latter deepens its channel and widens its valley, as both did formerly; but the other stream, having to work against more resistant rock, is not able to cut its channel correspondingly, and as a result loses drainage area to the former. Such piracy is not based upon land-tilting, but on rock structure. Furthermore, both land-tilting and variation in the hardness of the rocks are usually operative at the same time.

In some parts of the world normal drainage cycles have been suddenly interrupted by lava flows. A flow of lava, taking a

course across a valley, in a very short time forms a dam that may divert the drainage. This has never happened in Ohio. There are still other minor and infrequent natural operations that tend to produce irregular drainage history.

It is impossible to reconstruct the drainage history of Ohio from the time its area was first raised from the sea. Remote phases are quite beyond interpretation, and there is not complete agreement among students as to the details of more recent phases.

Under the leadership of Prof. W. M. Davis,[1] much progress has been made in the analysis of relief features, and in the knowledge of the processes involved. He has given the literature many terms that aid in the discussion of drainage evolution. When a tract in the shallow part of the sea margin is added to the continent, the first streams that form across it are called *consequent,* that is, the water finds inequalities in the surface, along which the flow is established to the sea. The streams of Florida belong to this class.

Remote Drainage of Ohio

Early consequent streams. When, late in the Permian period, the last portion of the Ohio area rose permanently above sea level, consequent drainage was established in the southeastern part of the state. The direction of these streams, and of the rivers already existing in other parts of Ohio cannot be demonstrated, but it is felt by many geologists that our area previously had been a portion of a great Mediterranean sea which for a long geologic time had occupied the region of the Mississippi basin; and that this sea only on rare occasions was connected with the Atlantic ocean across the central and northern Appalachian region. If this hypothesis is correct, it is probable that the original consequent streams had a southern course, to the diminishing inland sea, and later were tributary to a major stream which flowed southwest through eastern Kentucky and Tennessee. Possibly in the northwest part of the state, along the west flank of the Cincinnati arch, the original consequent streams flowed westward.

The Atlantic coastal plain drainage and the theoretical consequent drainage of part of Ohio in post-Permian times are not

[1] *Geographical Essays,* Boston, 1909.

unlike in principle. The rock material of the Atlantic coastal plain area was deposited by the streams flowing to the east and southeast, streams which carried sediment into the bordering ocean, whose currents distributed it; when this epi-continental tract was added to the land, the consequent streams also took a south and southeast direction, to which they still hold. The sediment that formed the rocks of much of Ohio was spread by streams, coming probably from a northern source, into a sea that grew deeper to the east and south; therefore, the natural dip of the rocks resulting from these deposits is towards the south and east.

Adjustments among consequent streams. Not long, geologically, after the region of Ohio was uplifted finally from the sea, or the sea withdrawn from it, the whole area, because of the mountain-making disturbance to the east, was warped. In the east this disturbance continued till the formerly horizontal rock beds were folded into the parallel ridges of the Appalachian mountains; in Ohio the disturbance is represented by the Allegheny plateau. This dynamic movement progressed very slowly; the rivers underwent adjustments, probably leading much of the original consequent drainage westward into the Mississippi basin, via northern Indiana.

The drainage pattern that develops in a shift from the consequent stream courses depends very largely on the relationship of the rock horizons in which the valleys are being cut. When the formations, which are not horizontal, alternate in hardness, and are transverse to the direction of the stream flow, ridges of resistant rock will appear across the area between the rivers, and *subsequent* streams will develop valleys laterally through the intervening belt of softer rocks; thus, the valley of the major consequent river has a gorge-like form alternating with wide mature reaches, because of the contrasts of hardness in the formations. With the lapse of time, and the succession of several incomplete drainage cycles, the ridges will be more and more obliterated. It is probable that the drainage pattern, developed in Ohio after the slow disturbances incident to the folding of the Appalachians, endured for a long time.

One can only offer suggestions as to the various steps between the original consequent rivers and the establishment of present drainage. Many investigators have studied this problem. Some

general principles in connection with drainage evolution in Ohio are understood, even though the complete history cannot yet be written. It is known that the relation of our continent to the ocean has shifted several different times since the Permian period. The altitude of the Ohio area has varied with these shifts. Following an upward movement of the land, stream work was accelerated; following a depression, the stream velocity was checked. Under the latter condition, flood plains would appear in the valleys; whereas the former movement would trench and remove material from the flood plains, and lengthen the rivers through piracy. Furthermore, it is generally felt that other periods of fairly static relationship between land and water existed; during such intervals, the streams and valleys tended to develop a complete drainage cycle. One such period, the Cretaceous, is said to have witnessed, in some parts of eastern North America, a base-level cycle. At the close of this period, the land area of North America was much diminished, and the epi-continental part of the ocean was very wide. The succeeding oscillation of the shoreline must have produced many changes in the streams. From this time, the drainage history of Ohio appears to admit of more satisfactory study.

Former river courses. So much of the state bears a deep mantle of glacial deposits that a long time may elapse before the buried river channels will have been located to such an extent as will warrant a satisfactory reconstruction of the old drainage of Ohio. In many counties, even where the land surface is level, well-borings have disclosed an irregular rock surface, sometimes cut up by the gorges of young rivers, sometimes showing the gentle slopes of old-age valleys. In the unglaciated area of the state the former drainage lines are more easily deciphered.

The problem of figuring out the river valleys of the past is further complicated by the fact that much of the glaciated part of the state appears to have been, from early times, a lowland toward which the rivers flowed from the non-glaciated area. Many abandoned valleys, conspicuous outside the drift sheet, have been followed into the drift-buried area, and their further tracing rendered impossible save where well-borings are numerous. For these several reasons, the map (fig. 1), giving a reconstructed drainage of Ohio, is largely hypothetical. Corrections will be made in time, particularly if activity in sinking deep wells should

continue. The former river courses here indicated are supposed, in the main, to have antedated the course of the Ohio river along the southern part of the state. Segments of these former stream valleys were united in forming the Ohio.

The central and western parts of the state, omitting the lake plain area, appear to have been drained by two important streams, each having a large basin and many tributaries, which united in or near Mercer county, flowing thence into Indiana. The course of the westernmost of these streams, in parts of Warren and Green counties, is indicated by the Little Miami; it passes thence across the southwest corner of Clarke county, and bears northwestward through Troy and Piqua into Shelby county.

The drainage history in the southwest corner of the state has been variously interpreted by different workers. One reconstruction gives two streams, rising in Kentucky, flowing northward, uniting near Hamilton into one stream which followed the course now indicated by the Great Miami through Dayton, northeast of which, in Clarke county, it joined the buried channel just described; the Licking river is one of the streams; its old course and present course are identical north to the Ohio, and Mill creek valley is its abandoned course northward from Cincinnati; the other stream flowed northward to Hamilton through the Great Miami valley. Another reconstruction assumes that the old Licking river turned to the southwest at Hamilton and made the valley which the Great Miami occupies in its course to the Ohio.

The central part of the state is today drained southward by the Scioto. The former river in this area, it is supposed, flowed to the north, its several tributaries rising in Kentucky and West Virginia. One of these branches, the Marietta river, had its headwaters in the vicinity of Parkersburg; for a few miles, the Ohio now follows its valley; thence this stream crossed Meigs county, and the northern part of Mason county, Ky., and continued westward through Gallia and Jackson counties, Ohio, uniting with another stream from the south, the old Kanawha,[2] in the vicinity of Beaver, Pike county. Near Piketon, the Kanawha joined the old Portsmouth river which also had its origin in

[2] Tight names this, Teays river. *Professional Paper 13*, plate xvii, U. S. Geol. Survey, 1903.

Kentucky and flowed northward through the present Scioto valley; from the vicinity of Manchester, to Portsmouth, the Ohio follows the valley of the former river. For a few miles north of Waverly the Scioto follows the valley of this old stream, in reversed direction; the river formed by the union of the Portsmouth and the Kanawha has been named the Chillicothe, the buried course of which is supposed to run west of north for some distance, then in a more westerly direction, uniting with another buried river in or near Mercer county. From the east, between Chillicothe and Columbus, the Chillicothe received two tributaries. The northern of these has been called Vernon river, as Mt. Vernon is situated in its old valley. The southern stream is named the Newark river, which was formed by the junction of tributaries in Coshocton county, and flowed westward past Dresden, Hanover, and Newark; the Muskingum today leaves this old valley in the vicinity of Dresden and flows southward through Zanesville, entering the Ohio at Marietta. In part of Muskingum county, and continuing into Licking county for a few miles west of Newark, this abandoned valley is a very obvious topographic feature.

The map of the former drainage lines of Ohio shows a river rising probably in Tuscarawas county, and flowing through Akron, north along the valley now occupied by the Cuyahoga river. South of Akron the drift is very level, giving no suggestion of the valley carving which it covers.

The Grand river is but a small portion of an old river which flowed northward; the present stream follows the former valley for a short distance. This old stream, the Pittsburg river, drained much of western Pennsylvania, and had its origin in West Virginia, being identical, south of Pittsburg, with the Monongahela. From the vicinity of Beaver, Pa., two branches have been traced southward; the easternmost passed the present site of Pittsburg; the course of the western branch is followed by the valley of the present Ohio to the vicinity of Wheeling and possibly as far south as Monroe county. Parts of the Allegheny were also included in the Pittsburg river basin, which is drained today by portions of the following rivers: Grand, Mahoning, Allegheny, Monongahela, and Ohio.

The above-mentioned rivers carved the main valleys in the former river basins of Ohio. These had numerous tributaries,

many of which have been worked out; some of them form parts of the present drainage lines. Several rivers which enter Lake Erie flow across buried valleys; at the place of intersection, the modern stream has a much wider valley than on either side of the former river course.

The development of the Ohio river. From the preceding discussion it appears that the Ohio, throughout the part of its course which borders our state, is a composite stream. Between these ancestral streams, important divides existed at the following points: (1) near New Martinsville, (2) in the vicinity of Huntington, W. Va., (3) east of Manchester, (4) between Cincinnati and the Great Miami. The Ohio river was brought into existence, then, by stream capture or piracy cutting down these divides. The order in which the captures took place cannot be stated, nor has it been demonstrated what was the agency that induced the captures. That the Ohio had practically its present course before the first ice invasion affected the state, is probable. It appears, therefore, that the direction of river-flow in the part of the old Pittsburg valley which bore a north-flowing stream from the vicinity of New Martinsville to Beaver, Pa., has been reversed. Reversals of flow have also taken place in some other segments of this composite river.

More satisfactory work has been done in unraveling the origin of the Ohio river than in other studies of former drainage in the state, for the reason that glaciation has only slightly affected this stream. All the rivers from the north, during most of the time that the ice was in the state, were heavily loaded with outwash, which silted up the valleys, even that of the Ohio to some extent.

Lake Erie Drainage

No large rivers, belonging entirely to this state, empty into Lake Erie; the Maumee, which is of considerable length, rises in Indiana. In the eastern half of the state the rivers are short, because the present divide between the Ohio and the Erie basins is nearer the latter. In the western half the rivers are longer but somewhat complicated, because of glacial deposits. I will briefly describe these rivers, commencing on the east.

Conneaut creek. This stream has its sources in Pennsylvania. Its course for several miles is quite parallel to the lake shore, a

direction of flow caused by the east-west trend of a moraine which the stream crosses a short distance east of Kingsville in Ashtabula county. After crossing the moraine, the creek turns eastward along the beach of glacial lake Whittlesey for about two miles; then it cuts through the beach, but after flowing north one mile its course is diverted to the east again by the abandoned shore ridges of lake Warren. At Conneaut the creek channels the Warren beach, and flows directly north to the lake.

Conneaut creek is a typical example of the influence which moraines and the beaches of ice-front lakes have exercised on the direction of post-glacial streams.

Ashtabula river. This stream also rises in Pennsylvania; it flows thence across the northeastern part of Ashtabula county. In some places the Ashtabula has cut a beautiful channel through the lower Pennsylvanian sandstones. Its course is very irregular where it crosses the moraine referred to above. The city of Ashtabula has grown along this river northward from its intersection with the Whittlesey shoreline; nearly the entire distance of three miles between this beach and Lake Erie, the river is bordered by this rapidly growing city, a response to the harbor facilities and the steel industry.

Grand river. This stream rises in Trumbull county and flows almost directly north to within about twenty miles of the lake, when it is diverted to the west by a heavy band of moraine. A few miles south of Painesville it bears northward again, entering the lake through a narrow gorge cut in Cleveland shales. Throughout the last mile of its course, however, its banks are not high. That the Grand river has been much shortened, perhaps in part through glacial interference, has already been stated (p. 391). In some parts of its course, a canyon-like cross-section shows how the declining level of Lake Erie, lower now by about 170 feet than the level to which the river was once graded, has tended to beautify all the streams now tributary to it.

Chagrin river. The major part of its basin lies in Geauga county, though its remotest tributary rises in Portage county. This stream also has precipitous cliffs through much of its course. The Cleveland shales have been easily eroded as the stream has lowered its bed to its present base-level. The multiplicity of tributaries from Geauga county represents the influence of the harder Pennsylvanian rocks.

Cuyahoga river. This river has a remarkable course. Its remotest source is not far from Lake Erie. Thence it flows south and west; near Cuyahoga Falls it turns to the north, entering the lake at Cleveland. One at once recognizes something irregular in this drainage pattern. Possibly glaciation has had much to do with its course; from Cuyahoga falls northward the river occupies a very mature valley. This maturity is such as would lead one to infer a genesis in connection with a much longer stream. At some time in the past a river which had its origin far south flowed northward, along the route taken by the canal to Akron (p. 391); and the present Cuyahoga occupies only the northern end of this former course. The south-flowing section of the Cuyahoga, starting in Geauga county, drains at first a hilly region, but from the vicinity of Kent its course lies in a level country. This flat plain contains many small lakes and swamps, and is obviously of glacial outwash and morainic origin. The falls occur where this northern section of the Cuyahoga turns into the valley of the former stream. Between Cuyahoga Falls and Cleveland some local irregularities in the river have been introduced through glacial interference.

Rocky river. The headwaters of this short stream are found in Medina county, whence it flows in two main branches that unite north of Berea. These tributaries have their origin in the more irregular topography of the Pennsylvanian rocks. At Berea and Olmsted Falls both branches have a waterfall, due to the Berea sandstone. Between these falls and the lake, the Rocky river occupies a gorge cut in the Cleveland and Erie shales. Northward from the point where the branches come together, the present channel flows twice across the channel occupied by a preglacial ancestral stream, which is called the Preglacial Rocky river. There is no more obvious case of drainage change in the state than this river.

Black river. This stream rises in Ashland county, flowing thence to Medina; west of Lodi it turns to the north and crosses Lorain county. The change of direction in Medina county appears to be due to an east-west moraine, to which the river is parallel. South of Grafton the river commences to flow on the Berea sandstone. Owing to the gentle dip of the Berea, it continues in this formation to Elyria. From Elyria northward to within about a mile of the lake the stream follows a rock channel

cut in the Erie and Ohio shales. Some of the smaller tributaries of the Black river in Lorain county exhibit the directive influence of the lake ridges.

Vermilion river. This is also a short stream. It rises in Ashland county, and because of a difference in rock structure has a flatter cross-section in the Huron county part of its course than has the Rocky river; but in the northern part of Huron county it cuts through the outcropping Berea sandstone into the underlying shales; this part of its course is a rock channel, in some places very beautiful. In the last two miles of its course the river is sluggish.

Huron river. The sources of this stream are in Seneca and Huron counties. It has a general northward course, passing Monroeville and entering the lake at Huron. South of the central part of Huron county its channel is cut in the Berea sandstone, locally forming beautiful scenery. Nearing Monroevill the underlying shale outcrops, and the stream has cut deeply into this easily eroded horizon; at Milan the channel shows fifty feet of shale bank. These cliffs gradually die out, and through the last four miles of its course the river has a wide valley and is very sluggish. Along the Huron, in the vicinity of Monroeville, the shales contain numerous large concretions; many have fallen from the banks and are so large that the stream does not at once carry them away.

Sandusky river. Of the rivers so far discussed, this has the largest drainage basin. Its numerous headwater streams start in Richmond, Marion and Hardin counties. Some of the tributaries flow to the southwest before joining the major branches. This direction of flow reflects the influence of moraine ridges on drainage; the glacial map of the state shows how the moraines in this part trend south of west. The Sandusky cuts into limestone throughout nearly all of its course; only at a few places does shale appear in the channel; the last few miles of its course, before emptying into the Sandusky bay, are in the area of the Monroe formation.

Portage river. This short river rises in Hancock county. Its basin includes nearly half of Wood county, a small portion of Sandusky county and some of Ottawa. The Portage has not cut a channel of much importance anywhere in its course; the rocks disclosed by it are limestone.

Maumee river. This is the major stream of many smaller rivers that belong to the northwestern part of Ohio. The Maumee itself rises in Indiana. Of its Ohio tributaries the principal are: on the north, the Tiffin river, which flows southward from Michigan, joining the Maumee at Defiance; on the south, the major tributary is the Auglaize, which rises in an extensive swamp section northwest of Kenton in Hardin county. One of the more significant tributaries of the Auglaize is Ottawa creek which rises near Ada, also in the swamp district. The Blanchard river, another branch of the Auglaize, flows from the same marsh area in Hardin county; for about twenty miles, its course is directly north; reaching the meridian of Findlay, it turns westward through Ottowa, and joins the Auglaize near Dupont. Many other smaller tributaries, on account of the direction of the moraines, also have a general westerly course. On its western side, the Auglaize has numerous small branches draining Paulding and Van Wert counties. The river takes its name from the fact that several of its headwater streams rise in Auglaize county.

From Defiance to Toledo, the Maumee is a very sluggish stream. It has not been of much use in navigation, as appears from the fact that a canal had to be built along its channel. Wood, Henry and Fulton counties give rise to several minor tributaries of the Maumee.

Ohio River Drainage

The longest rivers of the state are tributary to the Ohio. Many of these, when studied closely, show puzzling relationships. The Ohio itself has had an intricate history; some of its tributaries embody even greater complexities of origin, as already described.

Great Miami. The general course of this stream, whose basin involves about 4000 square miles, coincides with the axis of the Cincinnati arch. At first thought it may appear as an anomalous condition for a river to flow along the axis of an anticline. When such an anticline involves limestone formations, ultimately the drainage takes just such a course. The principles involved in the development of such a course have been fully discussed and

illustrated in drainage studies in the Appalachian areas, by Professor Davis.[3]

The remote sources of the Great Miami are in Hardin county. Since so many rivers rise in this county, it would appear that the region must have a relatively high altitude; the cause, however, is rather the glacial deposits which have converted much of the area into a great swamp. This swamp, in effect, is a broad divide. Numerous streams usually flow away from an extensive marsh area. From Dayton northward, the Great Miami has many branches. At Dayton it receives the Stillwater creek, and Mad river. Each of these tributaries is quite complex; the former drains nearly all of Darke county; the latter, Springfield and Champaign counties and parts of Logan. The remainder of Logan county gives its drainage to the Miami proper. Much of the surface water of Shelby county is gathered into Loramie reservoir, which overflows into the Miami. From Dayton southward, this river follows a mature valley, and only its tributaries at some distance from the flood plain show any evidence of youth. The Miami has no very long branches between Dayton and the Ohio river; on the west are several small creeks, some of them rising in Indiana. The junction of the Great Miami and the Ohio is formed just across the state line in Indiana.

Little Miami. This stream, about 100 miles long, has its source in Clarke county. Its basin, involving about 1850 square miles, includes parts of Greene, Clinton, Highland, Brown, Warren, Clermont and Hamilton counties. This river is parallel to the Great Miami; and its nearness to the larger stream accounts for its receiving from the west no branches of any consequence; on the east it has tributaries that rise many miles away.

Scioto river. The drainage basin of this stream is asymmetric: it receives few and short tributaries from the east, while the western side of its basin gives many long branches. The remotest headwater sources of the Scioto rise in Morrow, Crawford and Auglaize counties; its length is 210 miles, and it drains an area of 6400 square miles. An interesting feature of this stream is the numerous quite parallel branches that cross Delaware and Franklin counties. Of these the Big Walnut, Allen creek, and Olentangy are found within an east-west distance of ten miles; they are slightly

[3] *Loc. cit.*, pp. 434–441.

farther apart on the northern side of Delaware county. The Olentangy unites with the major stream at Columbus, while the Allen and Big Walnut creeks come together near Groveport, and a short distance south, join the Scioto. This arrangement of parallel streams may represent an inheritance from the excessive drainage of the immediate ice-front. The Scioto occupies a wide preglacial basin; and as the ice sheet assumed new retreatal positions, the drainage from quite a distance along its front centered toward the axis of this basin. Whenever the ice maintained a fairly stationary position, building up a conspicuous moraine, as it did in the vicinity of Worthington north of Columbus, great volumes of water flowed southward from the moraine.

South of Columbus on the west, the Scioto receives Darby creek from Logan county and Paint creek from Madison county. There are several other smaller streams that drain the western side of the Scioto's basin. From the east the Scioto receives but two branches of much length: Walnut creek rises in Fairfield county, and Salt creek has tributaries reaching into Hocking, Vinton and Jackson counties.

The lower course of the Scioto is rock bound, the channel being cut in the Waverly sandstone. Its fall even from Columbus to the Ohio is not great, about 200 feet in 90 miles. The Ohio canal follows the Scioto to Lockbourne.

The barbed pattern formed by the Scioto and its tributaries is the best example of normal river arrangement in Ohio. When a tributary joins its major, the smaller angle made should be on the upstream side; this forms the barbed pattern. If you examine the relationship between major and tributary streams throughout Ohio, you will note how nearly the Scioto basin conforms to the barbed arrangement.

Between the mouth of the Scioto and the mouth of the Hocking river, the Ohio receives very few tributaries, and all of these are small. The first one upstream is called the Little Scioto; its drainage basin extends across Scioto county, and includes the southwestern part of Jackson county. Another of these streams, Symmes creek, has its source in Jackson county, and flows southward through Gallia and Lawrence counties; it crosses an irregular country, a region of Pennsylvanian sandstones and conglomerates. The Raccoon creek, the largest of these tributaries, rises in Hocking county, and flows directly south through Clinton and Gallia

counties to the Ohio; some of its branches drain portions of Athens and Meigs counties. The Raccoon is an irregular stream, its valley having wide and narrow stretches alternately; such a relationship suggests a composite history. Meigs county is drained entirely by minor creeks tributary to the Ohio.

Hocking river. This stream has a length of about 100 miles and a drainage basin of approximately 1200 square miles. Its remotest source is in Fairfield county, and its numerous tributaries form a basin including parts of Perry, Morgan, Hocking, Washington and Athens counties; this basin involves rocks of the Pennsylvanian period, consequently it drains a rugged region. Its bed has a fall of about 240 feet, but not a uniform slope; in some segments of the valley the stream has very little flow, while in other segments it is cutting into rock.

Muskingum river. This has the largest basin and is the longest stream in Ohio. Its length is about 200 miles, and the area drained has been estimated as 7,740 square miles. The maximum width of this basin is 100 miles. One of its major tributaries rises in Medina county, within about 40 miles of Lake Erie. The Muskingum proper is formed by the junction of two streams, the Walhondling and the Tuscarawas. These meet in Coshocton county; the name, Muskingum, is applied to the river south from this point of junction. Each of these uniting streams has an irregular course and numerous tributaries. The Walhondling drains parts of Knox, Morrow, Richland, Ashland, Medina, Wayne, Holmes, and Coshocton counties; the basin of the Tuscarawas embraces all or parts of the following counties: Harrison, Belmont, Carroll, Columbiana, Stark, Summit, Medina, Wayne, Holmes and Tuscarawas. It is thought that glaciation has been an important factor in producing the irregularity of both these streams. The country drained is rough, since throughout most of it the coarse Mississippian and Pennsylvanian rocks are on the surface.

Will's creek, the basin of which includes all of Guernsey, and parts of Belmont, Noble, Monroe and Coshocton counties, joins the Muskingum about 10 miles south of the junction of the Walhondling and the Tuscarawas. The next important tributary of the Muskingum is the Licking, with which it unites at Zanesville. The basin of the Licking embraces practically all of Licking county and portions of Knox, Perry, and Fairfield coun-

ties. The Licking is a composite stream, the result of drainage modifications antedating the last glacial epoch. Between Zanesville and Marietta the Muskingum receives no important tributaries, no creek more than 20 miles long.

So far as investigation has proceeded, the Muskingum also surpasses other streams of our state in its interesting history. Students were early attracted by the drainage irregularities so obvious throughout its basin. Many of these have been unraveled, so that now it is possible to trace the history of this river to an early date.

Following the Ohio upstream, from Marietta to the Pennsylvania state line, we find no important tributaries, and only two that measure more than 20 miles in length. Entering the river less than two miles east of Marietta, is Duck creek, which drains most of Noble county and receives some accessions on its way to the river through Washington county. About two miles farther upstream, we find the Little Muskingum, which rises in Monroe county and takes an irregular course southwestward, parallel to the Ohio river.

The divide between the Ohio river and the Muskingum is so near the Ohio that it receives from the west no important branches between Marietta and East Liverpool. In time these short Ohio tributaries may push their headwaters westward at the expense of the Muskingum drainage basin.

Little Beaver river. Most of Columbiana county is drained by this stream, which has numerous branches. It is a short river but embraces some interesting features. A small part of its course, just before meeting the Ohio, lies east of the state line.

Mahoning river. Portions of Trumbull, Portage and Stark counties and nearly all of Mahoning county are within the basin of this stream, which joins the Beaver river at Newcastle, Pa. Its headwaters reach into some high altitudes where the Pennsylvanian formations outcrop.

Summary

There is much variation in the character of the relief of Ohio; but the areas illustrating the different types are not set off sharply from each other; they blend so well that the observer scarcely notes the change in passing from the youthful topography into

the more mature dissection. From the standpoint of the river cycle now in operation, there is no typical old age topography in the state; on some uplands, between troughs that are still being deepened, one may see the broad gentle slopes of old age, the remnants of an older base-level period.

Lake plain area. In the north and northwest parts of the state, the relief is youthful. This is the region of the old lake plain and the adjacent prairie land. The streams, since the retreat of the glacier, have been working to the base-levels formed by the different stages of Lake Erie; there have been three important stages preceding the present (p. 214). Nearly all these rivers have gorges that extend back a few miles from the lake; the size of each gorge varies with the texture of the rock in which it is cut. At a few places along the lake the streams are carving their channels entirely in glacial drift; but the glacial drift, the shale, and the soluble limestones, yield quite readily to erosion.

Another feature of the youthful topography in the lake plain region is the extensive swamp areas; a long time will elapse before the rivers will have pushed their tributaries across these swamps. The state, therefore, is constructing artificial channels which lead to the nearest streams, thus hastening what nature unaided would do in time.

Plateau area. In the plateau area there is much more dissection. Here are the headwater branches of the streams that belong to the Ohio river and to the Lake Erie basins. This condition of more advanced relief is not constant throughout the area. In some parts post-glacial rivers have done but little trenching, and the relief is largely the work of older drainage; the surface is rolling and the minor divides are very irregular.

The Ohio river is the immediate base-level of all these south-flowing streams, but at particular places along their courses horizons of resistant rock form local base-levels, to which the upstream parts for varying distances become graded. The whole area is quite thoroughly drained; the stage is mature, but less mature than would be anticipated at such a distance from the sources of so long a river as the Ohio. The absence of relief of at least an early old-age stage, in southern Ohio, considering the length of the Ohio river, is due to the origin of this river, as already explained (p. 392). Down the river towards Cincinnati the relief is more immature; the stage of dissection, however, does not

change uniformly upstream, a condition which reflects the river's composite origin; the divides between the segments of the streams which were united in forming the Ohio river are characterized by more youthful dissection. Throughout the whole of the plateau area the streams are fairly well adjusted to the rock structure.

Altitudes. Ohio has an altitude range of about 1100 feet. The highest point, 1540 feet, is in Logan county; the lowest, 440 feet, is the low-water mark at Cincinnati. The Ohio river drops about 220 feet in the 436 miles of its course along the state. According to the *Dictionary of Altitudes*[4] the following are the altitudes for the low-water mark at various points upstream from Cincinnati: Maysville, Ky., 448; Portsmouth, 468; Ironton, 483; Marietta, 570; Moundsville, W. Va., 614; Wheeling, W. Va., 622; Steubenville, 641. The Wellsville topographic sheet shows the 660-foot contour crossing the river at East Liverpool.

Lake Erie is 573 feet above sea level; within the lake plain region are included the adjacent areas below 800 feet in altitude. A relief map of the state shows that the plateau area consists of five north-south blocks that are over 1000 feet high; these are separated by lower strips through which flow the important rivers of the state. In the south central part of the state, between the valleys of the Scioto and the Muskingum, the general altitude is less than 1000 feet. The north-south blocks of higher altitude increase in surface irregularity and in irregularity of outline from west to east; the most eastern block does not contain any east-west gaps north of Washington county. The general parallelism of these blocks, their ragged outlines, and the intervening lower strips, have exerted a strong influence in the industrial development of Ohio.

[4] U. S. Geological Survey, 1906.

GEOGRAPHIC CONDITIONS IN THE EARLY HISTORY OF THE OHIO COUNTRY

FRANK CARNEY

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ROUTES TO OHIO

A colony is much more than a trading post; a colony is a group of people devoting themselves to procuring a living from the soil. No new land is ever permanently occupied until it has been divided into farms. The settlement of Ohio commenced

when farm homes were established within its borders, not when fur-trader's posts were located.

Certain physiographic conditions are factors in the exploration and the succeeding settlement of the lands. Man in later centuries may progressively become less subject to the physical features of the earth; but he will never become able to ignore them. Mountains will always be mountains to him; plains, low easy places for his activities; and rivers, the lines of his movement across the lands. This is just as true when he moves no longer on boats, but in freight cars and Pullmans; river valleys attract railroads as well as the overland caravans of pioneers.

Reports of the beauty of the Ohio country, its great river and lake, had come to the ears of white men through the Indians. Sporadically, for several decades, men from the coast colonies had attempted to reach the region, but were thwarted. Without the modern methods of travel, to set out for a terminus several hundred miles away in a wilderness, is a serious matter. Even today the area is reached usually by definite physiographic routes. Four routes were used in the early days.

St. Lawrence river. An explorer, entering North America by the St. Lawrence and keeping away from the southern shore of the lakes, on his way into the interior, would cross the narrow river between Lakes Erie and Huron. By this route, many of the early French travelers reached the northwest territory. Doubtless they might have chosen a route lying south of the lakes, but because of a serious mistake made by an early French explorer, Cartier, the Indians living south of Lake Ontario were bitter enemies of the French; the French, except when prompted by missionary motives, usually kept away from the southern shore of Lake Ontario. Probably the first white man who visited the Ohio area entered this western country by the northern route.

Mohawk pass. Another way of approach is through the lowland of New York State, the Mohawk valley, which is the lowest gap across the Appalachian mountains. This is the route through which today moves the bulk of the industrial output of the Mississippi valley on its way to the Atlantic cities and to Europe. The Mohawk lowland afforded a convenient water-course to the west, Clinton's "ditch," joining Lake Erie and the ocean; and later became the route of those great, effective lines of railroad, the New York Central and the West Shore, the extensions of

which through Canada and northern Ohio now form connections that reach to the Pacific. The most natural and therefore easiest approach to Ohio from the Atlantic is across New York State, but it was not the route taken by the first settlers who came into Ohio.

Mississippi river. Ohio may also be entered from the west, through a door as wide as the distance between Lake Erie and the Ohio river. An explorer ascending the Mississippi, following the Ohio to the east, and one of its larger tributaries to the north, would have found an easy portage to the Maumee, thence into northwestern Ohio. Joliet appears to have entered Ohio from the west, but it is not known where he crossed what is now the state line.

Appalachian gaps. The fourth route into Ohio is one which, as far as settlement is concerned, was the first used, the route across the Appalachian mountains, gradually rising many hundred feet above sea level, and then slowly dropping into the low plateau and the plains beyond. The altitude of the Appalachians was formidable; their rugged wilderness condition, extending three hundred miles when crossed by the most direct route and much longer when crossed by other passes, was forbidding. Traders and adventurers occasionally worked their way over the barrier; but colonists did not attempt it till compelled to do so.

Every river that enters the Atlantic was tried for "South Sea" affiliations, during the days of exploration. Each explorer thought: this is the strait that will lead me through the barrier of land between European markets and the wealth of the East. The Potomac was thus explored; it did not lead to the silks and spices of Asia, but later was effectively used both for canal and railroad to transport the far more valuable coal and grain of the Allegheny plateau and Mississippi basin.

The Potomac rises near the Cumberland pass, on the west side of which the pioneer had a choice of route, either northward down the Youghiogheny and Monongahela to Pittsburgh, or more directly westward towards Wheeling. This pass through the Appalachians was much used, used even by emigrants from New England. The route itself did not attract settlers, for the mountains were rough, and the valleys heavily wooded; the emigrants therefore pushed westward into the plains beyond. The

Hudson and Mohawk valleys, on the other hand, tempted emigrants to stop at every point; consequently the New York route itself was found attractive and was settled almost completely by the Dutch, whereas later colonists had to push on farther west.

Emigrants from the southern settlements, after crossing the Blue Ridge mountains, sometimes proceeded southward through the Great Valley to Fort Chiswell; at this point they turned to the west across the Holston and Clinch valleys, and through the Cumberland Gap into the "western" country.

Early Efforts to Reach the Ohio

In recent decades immigration to Ohio has been very active, drawing people mostly from two extremes of social and financial standing. Her numerous and evergrowing industries are attracting laborers from Europe, and capitalists from other states. These two sources are making valuable contributions to her list of citizens.

La Salle. It is doubtful, however, whether any man who has come into Ohio since the French and Indian War sought the area more eagerly than did La Salle in the seventeenth century. La Salle was an intrepid explorer, and gifted with much diplomacy in dealing with the Indians; he sojourned for some time among the Iroquois in central New York. While he and his two Sulpitian companions were with the Iroquois, they frequently heard of a mighty river lying towards the west, which the Indians called "Hohio;" naturally La Salle wished to see it. They told him that one could march many days along this beautiful river, and at last would come to the dropping-off place, the Indian's designation for the seashore. La Salle saw the possibility of this being the river that leads on westward to the "South Sea" which laves the shores of India, consequently he decided to locate the "Hohio," and determine its relations.

The three Frenchmen set out on a journey of exploration, but this trip shortly came to an end, in a way least expected.[1] In the wilderness, as they moved towards the west, they were very much surprised at meeting a Frenchman, Joliet, who for years had been wandering about the upper Mississippi basin making

[1] Parkman, *La Salle and the Discovery of the Great West*, pp, 12–27. Boston, 1884.

maps, helping the Indians, studying natural history, much of the time all alone. Joliet advised the two priests, who were accompanying La Salle, that it was their duty, instead of seeking unmapped rivers, to proceed to the Ottawa Indians who needed their ministrations. These Sulpitian monks respected Joliet's advice, and started on their way to the Ottawas.

La Salle was left alone to find the Ohio river. The record of his travels the next four years is not entirely clear; there are many statements concerning the extent of his explorations, and some of the allegations have been examined and accepted by modern historians. It is generally conceded that La Salle discovered the Ohio river, probably in 1669. It is certain that after parting with the Sulpitians he returned to the Iroquois, procured guides and proceeded again to the west, keeping south of Lake Erie, where any one of many tributaries might have directed his course to the master stream. In a later century, water communication between the Ohio river and the Mohawk lowland was established through the Erie basin, and a few years after this, by the same basin, railroads brought the upper Ohio region into industrial relationship with New York City. Geographic conditions favored La Salle's enterprise.

The Virginian expedition. Another attempt to reach Ohio was made in 1671. A party was organized by Governor Berkeley, of the great colony of Virginia. Lands extending westward across the Appalachians had been granted to this colony, and Governor Berkeley wished to know something of this unexplored region. There were frequent reports as to the country beyond the Appalachians; one common report was that on the other side a man had seen a mighty river that flowed across the horizon westward. It was suspected that this river might lead into the "South Sea." The governor accordingly organized a party, under the command of one Thomas Butts, to be guided by Indians. They set out, and journeyed about twenty-nine days; at first they passed southwest through a valley, but the last sixteen days they followed a northwest flowing river. The first part of the journey was doubtless along the Greenbrier. After traveling some days to the northwest they noted a mighty roaring and farther on found its cause, the great falls of the Kanawha. The commander was unable to get his Indians to go beyond this point; it was a frightful country down the river, they said, a place where no drinking

water was to be had. So the expedition came to an end, within easy reach of the Ohio river. The route of this party is the most feasible one from central Virginia, the one selected for the Chesapeake and Ohio Railway.

Claimants of the Area Now Ohio

Its geographic relationship to other regions often decides the ownership of a particular area; and for the same reason, the "other regions" may shift from one master to another. The application of this principle is best seen in accounting for the changes in the political affiliations of a state or a nation. Several peoples have claimed to own the region of which Ohio is now a part.

Claim of the Iroquois Confederacy

The Five Nations claimed this territory, having acquired it, they urged, through conquest. It is a fact that this combination of strong eastern tribes did drive out of the Ohio, Indiana, and Illinois areas all other Indians, making thorough conquest to the Mississippi river. Having done this, the Five Nations asserted that they owned the territory; and on the basis of this claim, at a later period, deeded it to the British, who based their ownership on this deed. In recent years, the Museum of Natural History of New York State has brought to light many facts bearing on this Indian conquest; much of the data was procured from Indian sources, and is quite as pertinent as the English discussions of the title which the Iroquois transferred. The evidence appears to show that the Five Nations, through a campaign which was the more easily made successful by causing it to be understood that they were aided by powerful white allies, either defeated or spread consternation among these western tribes. Many of the prairie Indians fled, and very few fell into the hands of the Iroquois. Gradually these dispersed tribes moved again into their own territory, and reoccupied it successfully as far eastward as the Muskingum valley. Furthermore, all later attempts of the Five Nations to dispossess them were successfully thwarted, largely because of the organization made among these Indians by La Salle, who in the meantime had returned from France with a royal license to carry on his fur trade. He, in a way, is respon-

sible for the western Indians reoccupying the territory out of which the Iroquois Confederacy had driven them.

Such a temporary conquest, followed shortly by a reassertion of power on the part of those who had been dispossessed, hardly constitutes an equitable title; but it was satisfactory to Governor Nanfan of the New York colony, who procured the deed for the English. This whole question was reviewed very critically in 1839 by General William Henry Harrison, in whose opinion the Five Nations never established a right to land west of the Scioto river;[2] General Harrison conceded what others did not, the distance between the Muskingum and the Scioto.

CLAIM OF THE FRENCH

Basis of claim. Frenchmen, however, asserted ownership over this territory. North America, as a continent, was claimed by Great Britain on the basis of discovery made by John Cabot, who did discover an island off the eastern coast of Canada. If there was any virtue in this claim, surely the nation whose citizens first walked over much of the continent itself could well assert its title; accordingly this Ohio country belonged to the French, because her emissaries in evangelization and industry had tramped this basin back and forth for about a century before the French and Indian war. Not only had they founded trading posts, but they had organized a few colonies, whose industry, even in the manufacture of wheat flour, was felt in Europe; the first shipment of flour went southward from the Wabash country in 1746.[3] The French, entering the continent through the St. Lawrence river, spread easily across the low divides of the Great Lakes' basin into that of the Mississippi, and with scarcely less difficulty through certain adjacent parts of the Allegheny plateau.

The particular part of the basin in which we are interested was visited first by Joliet. More than this, the industries of the whole region were monopolized by the French for many decades before any competition appeared. At several points along the Great Lakes, the French maintained trading posts which were widely known among the Indians, much to their advantage.

[2] R. King, *Ohio*, p. 40, in American Commonwealth Series.
[3] B. A. Hinsdale, *The Old Northwest*, 1889, p. 50.

Competition in fur trade. In 1664 an English ship entered New York bay, representing the Duke of York; it anchored off New Amsterdam. A force was landed, and shortly the British had conquered the Dutch, New Amsterdam becoming New York. Not long after that this English colony was governed by an Irishman named Dongan. Dongan had learned that there was great profit to be had in exchanging flashy articles with the Indians for furs. With his sanction, English traders made a trip by way of the Mohawk lowland up the Great Lakes as far as Mackinac, in the summer of 1686. Durantaye, the commandant in charge of the garrison at Mackinac, was absent. The British furnished the Chippewas with flashy goods and rum, obtaining all the furs they had. When the Frenchmen returned, they discovered the loss of a season's profit. The trip was so successful from the English traders' point of view that they decided to repeat it the following year; the governor himself became a patron of this second expedition, and sent a guard of soldiers to accompany them, under command of Major Patrick McGregor. This semi-military proceeding was a confession on the part of the governor that the method of the preceding year was not entirely commendable. The French, in the meantime, suspected that the trip might be repeated, and laid their plans accordingly. They did not even wait for the English to reach Mackinac, but met and captured each of the two flotillas into which the English party was divided. Major McGregor and his soldiers were well cared for as prisoners; the traders and their cargoes were turned over absolutely to the Indians.

The French took steps at once to see to it that a repetition of such trade exploits as this should be hazardous for the English. Other points south of Mackinac were fortified, and trading posts were more widely distributed. Cadillac, in 1701, was ordered to establish a fort where Detroit now is, and properly fortify it. These trading posts in Indiana and Ohio were subject to the fort at Detroit; such posts were established at Sandusky, along the Cuyahoga, and the Maumee, and wherever else in Ohio the Indians were in the habit of congregating.

Equity of claim. A sense of fairness will grant that, so far as discovery bears with it equity, this region, including Ohio, was rightly claimed by the French. If peaceful association with the primitive inhabitants is itself evidence of rightful ownership,

it belonged to the French. If, on the other hand, the planting of colonies and bringing the area under agriculture, is necessary for ownership, only a small part of it can be said to have belonged rightfully to the French, because they looked upon this great area more as a field for trade with the Indians than as a section which they might colonize, and from which they might win agricultural returns. In only one part, away from the immediate environment of the St. Lawrence, did the French have agricultural colonies; in sections of Indiana and Illinois, the central points of which were Kaskaskia and Vincennes, they did colonize, and some agricultural returns from these communities reached Europe.

CLAIM OF GREAT BRITAIN

Royal charters. From the premature efforts of Walter Raleigh to the time of the regular plans of James Oglethorpe, the decades abound in charters issued by the British kings to loyal subjects, granting boundless lands in the New Continent, of the limits of which they were entirely ignorant. These charters were usually inexpensive; and many favors to royalty were rewarded by issuing charters to cover unknown territory in America. Slight effort was made to collate the boundaries of these land grants; frequently different individuals and companies had charter titles to the same territory. These charters are not very interesting reading today; they are buried in the customary verbiage of Anglo-Saxon law style. The grants were not accurately defined; sometimes the northern and southern limits were fixed by degrees and minutes of latitude; the westward limits, if referred to at all, were supposed to be the "South Sea," or the Pacific Ocean, but nobody knew its location in reference to the grants.

Discovery by John Cabot. But the English based their ownership of America as a whole on the right of discovery by John Cabot, a Mediterranean citizen whom the English had hired to explore for them. John Cabot had scarcely done more than to sight the mainland, but this was ample in a land so large that generations passed before interests became too conflicting. At length, with the expansion of settlements and the activity of traders, collisions between the English and French arose. Then England established other claims to territory not already in

their possession. This came first through their affiliations or alliances with the Five Nations, the Iroquois Confederacy.

Deed from the Iroquois Confederacy. The very year that Cadillac made a military post at Detroit, 1701, Governor Nanfan of New York colony met the Indian chiefs where Albany now is, on the Hudson river. These Indian chiefs were themselves somewhat frightened; they had learned of the successful aggressiveness of the French in reference to the English trade. They were aware of the fortified settlement at Detroit and of the minor posts at different points of Ohio, Indiana and Illinois. They had been made ignominiously aware of the prowess of the western Indians under French organization and guidance. Consequently the Iroquois Confederacy was ready to form a mutual alliance with the British. July 19, 1701, this Confederacy deeded to Great Britain, through the governor of New York, land won by conquest, including a strip 800 miles long and about 400 miles wide, which, they said, their fathers had acquired by conquest some eighty years before. Thereafter, so far as this part of North America was concerned, the British jurists could urge better claim than Cabot's discovery. All the nations of Europe from the time of Philip of Macedon had accepted conquest as a sufficient reason for claiming ownership. Nevertheless, another governor of the New York colony, twenty-five years later, had this deed renewed by the Iroquois Confederacy.

France and Spain did not contest England's ownership of the coast colonies land. That narrow strip between the Appalachians and the sea the English were left to colonize, but both countries said that England's territory ended with the crest of the Appalachian mountains; and that the region of the streams which had their sources in the Appalachian mountains and flowed westward belonged to them. England's claim to the whole area was urged on the basis of discovery by John Cabot, and to a particular part of the Mississippi basin on the basis of deed from the Five Nations. Nevertheless, to trace the evolution of England's ownership requires reference to other transactions.

The French and Indian War. It was inevitable that France and England should clash in this country. The rivers of the Atlantic slope occupy beautiful valleys, which tempted congested population across into the valleys and plains beyond the moun-

tains. The Atlantic coast was being overpopulated rapidly, and already many of the hardy Anglo-Saxon colonists had scaled the divide and were living in the Mississippi basin.

Only resolute people were colonists in early times; the sturdy characters of old communities became frontiersmen. Today travel is easy, and the struggle upon arrival is tempered by industrial opportunities. But in the early days it did require some courage even for the journey, and much faith for the struggle in the wilderness; usually only the fittest men and women faced these. The most courageous of the sea-board settlers found their way over the Appalachians, and they went for the purpose of making homes, but this movement into the wilderness of the west was obstructed by the French and the Indians.

The border disturbances were intermittent but chronic. Often the Indians were urged on by the French traders and *coureurs des bois*. The regular outbreaks between the Frenchmen and the British colonists in America were always side issues of open warfare in Europe. The "French and Indian War," terminated by the treaty at Paris, was the American side of the Seven Years' War. In this struggle France lost her American possessions. King George of England then became the monarch of all North America east of the Mississippi river. Heretofore the section west of the Appalachians had been "royal domain" under the French king; now by the "King's Proclamation," October 7, 1763, this became "crown" possessions of George III. Where then did the charters of the colonies come in, those generous charters, most of which mentioned lands reaching to the west as far as the "South Sea?"

George III's "royal domain," and the Quebec Act. King George in this proclamation expressed particular concern for the Indians; he desired to protect them against the encroachments of the whites, who, as we have already seen, were converting their hunting grounds into wheat and corn fields. The King forbade settlements beyond the basins of the Atlantic colony rivers; and he directed, furthermore, that all persons already beyond these limits should remove at once. Complaints arose among King George's subjects on this side of the Atlantic. Many ardent spirits of the older colonies, even before the French and Indian war, had fixed their abodes west of the Appalachians; others continued to do so. As loyal soldiers of their king, they had

marched through many valleys tributary to the Ohio; they learned how desirable was this territory from which they had been almost entirely excluded by the French. But legally they were no better off after their important aid to the British victory over France; their own countrymen continued the plan of the French governors and traders.

Another effort on the part of Parliament seemed necessary to keep the colonists out of the Ohio valley. The Quebec Act of June, 1774, made the region between the Ohio and Mississippi rivers and the lakes a part of the province of Quebec; the whole area was to be governed from Quebec, and the coast colonies therefore were shut off from any legal association with it. After the treaty of 1763 officers had been sent to the various posts which the French had established. Some of these were very tactful in their association with the Indians, but others were not. Trouble continued; the presence everywhere among the western Indians, of French voyageurs and similar nondescripts from the English settlements did not tend to peace.

Difficulties with Indians in enforcing claim. After the success of the English had been assured, but before the treaty of Paris was signed, Sir William Johnson visited Detroit and other points in the recently acquired territory; his object was to conciliate the Indians, and he returned, feeling that he had won their support for the English. It was not long before the English learned that the very chiefs whom they had entertained were perpetrating a revolt; Pontiac's war soon broke out; from the standpoint of the Indians, it was a success; probably two thousand whites were slaughtered, and only two posts were left in the hands of the British, Fort Pitt and Detroit. The western Indians were still loyal to the French. It was necessary for the English to demonstrate their ability to control this region, the Indians and renegade Frenchmen. At once expeditions were sent out; one from Fort Niagara under Colonel Bradstreet, another from Fort Pitt under Colonel Bouquet. Bradstreet was to take his force up the Great Lakes as far as Mackinac, then return south to Sandusky and meet Bouquet, who in the meantime was marching westward from Fort Pitt through the central part of Ohio. Before Bradstreet had proceeded far, however, he was met by a delegation of very penitent Indian chiefs, of the Delaware and Shawnee tribes; they convinced Bradstreet of their sincerity; nevertheless, at

that very time their warriors were continuing the butchery of frontiersmen. Bradstreet at once sent a message southward to intercept Bouquet, informing him that an armistice had been concluded, but Bouquet read between the lines the real situation, and continued his march into Indian territory. After reaching the Muskingum river, he established a camp near the site of Dresden. Within two days the chiefs of the above tribes, also of the Senecas, appeared on a mission of peace. Colonel Bouquet had had experience with the Indians; he read from their faces what their lips did not say. The Indians feared this man whose strategy had saved Fort Pitt the year before, and within a few days he succeeded in making these chiefs acknowledge what they had really been doing. After their conference with Colonel Bradstreet, they had improved the interim by removing some remaining whites who had escaped former pillages; it was their hope to befog this other colonel, so that they might have time for completing the carnage. But Bouquet knew how to negotiate with Indians; he drew from their own lips the testimony which convicted them. He kept the chiefs in suspense several days; at last, in a final audience he gave them to understand that they could secure peace only by delivering to him within twelve days all the prisoners they had taken from the settlements.

This demand was complied with to the satisfaction of Colonel Bouquet. The Indians delivered 206 prisoners, 81 men, the rest women and children. This outcome of the expedition was eminently satisfactory to all parties concerned. Thus the British gradually developed confidence between themselves and the Indians in this country; and this confidence was seldom abused till after the Revolutionary war, when trouble commenced again, partly through the lack of diplomacy on the part of the white men.

The trans-Appalachian area secured to the English. The claim of England to a large part of America was established by their defeat of the French. In addition to the terms of the Treaty of Paris, 1763, by which French influence theoretically terminated, the English were making progress in getting on with the Indians. Still there were many conflicting interests to be harmonized. The French settlers, by this treaty, were shifted under a new religious and legal control; the English settlers were disappointed and vexed over the disposition made of the acquired territory that

backed their narrow seaboard holdings; and companies in England were always devising new plans for exploiting the colonies.

Even without the assistance of the mother country, the English colonies eventually would have gained the trans-Appalachian territory. Their compact arrangement on the seaboard, with the protecting mountain barrier on the west, conserved their energy without loss during the aggressive period of French trade expansion in the interior, and gave momentum when the colonists assumed the aggressive. The French military posts were too far from their base, France, for they had not made a business of developing colonies in America; there were no overpopulated areas in New France. No barriers had imposed intensive growth on the French settlements. Before the final struggle, the English colonists were practically in possession of the Mohawk pass, and were familiar with the breaks in the mountain barrier farther south.

CLAIM OF VIRGINIA

King George, as soon as the Treaty of 1763, terminating the French and Indian war, had been concluded, proclaimed this territory "royal domain," and asserted that the colonies had no more business in it; that it was to be held for the Indians. The British fur-trading companies were active; it was decidedly to their interests to keep Canada and the Mississippi basin one great game preserve, and the redmen as tenant trappers. The zeal with which the colonies went into the French and Indian war was partially selfish; they wanted more land. It was to be expected that the king's disposal of the lands acquired from France would cause disappointment in the colonies. This, they thought, is not gratitude; it is selfishness.

Population of Virginia. For more than a century before the Revolution, Virginia was the most populous of the colonies.[4] The need for more territory was imperative. Even before the French and Indian war, frontier settlements had been made in the Shenandoah valley. As fast as the resistance of the Indians could be overcome, the head streams of the Ohio's tributaries were dotted with cabins. When the more attractive areas near the major stream could be occupied, the wilderness of the western

[4] *A Century of Population Growth in the United States*, p. 9, Washington, 1909.

Appalachians was deserted except by the west-bound pioneer. Geographic conditions thus account for the first trans-Appalachian settlements being opposite Virginia.

Dunmore's Indian war. Dunmore, the royalist governor of Virginia, decided that he would take the initiative in punishing the Indians who continued to harass Virginian frontiersmen. Though George III had forbidden settlement in the western valleys of the Appalachians, or the fertile plains beyond, Dunmore led a force into this northwest territory, for the purpose of subduing these tribes. Dunmore organized two forces to proceed into the Indian land; one under Dunmore himself went through western Pennsylvania; the other, under General Lewis, appears to have moved directly from Virginia through the Greenbrier valley, thence down the Kanawha. The second division, in October, 1774, at the mouth of the Kanawha, met and defeated a band of about one thousand warriors commanded by the famous chief, Cornstalk. General Lewis had in his command about one thousand five hundred frontiersmen of Virginia. This battle was really the beginning of the Revolutionary war. Here, not at Lexington, the first blood was shed in resentment of George's policy. After the battle of the Great Kanawha, Lewis crossed the Ohio river and proceeded to join his commander who had constructed a fort near where Chillicothe now stands. Already the Indians had begged Governor Dunmore for peace, and a treaty was made, the Indians assenting to their conquerors' demands.

Dunmore placed the rights of subjects above the whims of kings. The colonists moved westward in spite of George III. Unfortunately the Indian onslaughts were sometimes inspired by the representatives of Great Britain, usually narrow-minded officials and traders, and occasionally the hasty acts of the settlers aggravated matters. Race evolution made it necessary to displace the Indians; it was a question of survival. Governor Dunmore doubtless felt that if he could overawe the Indians, the colonists might move on in greater numbers and so firmly occupy the area that the Quebec Act would be futile.

Campaign of George Rodgers Clark. The just rebellion of the colonies against the selfishness of the mother country was imminent in the resolutions placed before the House of Burgesses by the Virginian, Patrick Henry. During part of the Revolutionary war he was governor of his state, and in that position rendered his country valuable service.

Virginia, at the beginning of the war, had numerous citizens living in Kentucky. One of these citizens, George Rodgers Clark, petitioned Patrick Henry to be commissioned to look after the region north of the Ohio; his wish was granted. This area was inhabited by Indians who for some time had been living peacefully, and by many quiet French settlers. Clark, with a small body of volunteers, moved northward, and took possession of the various forts which were in command of English officers; he planned to proceed as far as Detroit, but was unable to muster sufficient force. Clark held what he had gained, waiting the outcome of the war. During this interval he maintained very pleasant relations with both Indians and French. Virginia exercised authority over the area, making it the county of Illinois. The inhabitants "professed themselves subjects of Virginia," and "took the oath of fidelity."[5]

If conquest warrants possession, this whole region belonged to Virginia, whose territory, therefore, was larger than the other colonies combined; it included Illinois, Indiana, Ohio, Kentucky and West Virginia.

Influence of Clark's campaign in Peace of Paris, 1783. The real significance of Clark's work appeared in the peace negotiations. If the Americans had not secured and held the scattered British posts in the Northwest territory, their representatives at Paris could not have insisted on its being included in the terms of peace. France and Spain, as well as the American states, were parties with England in these negotiations. Honesty and frankness did not characterize all diplomatic relations of that century. At this time the new Republic felt that France was her friend. Our chief representative was Benjamin Franklin, a man of such absolute honesty that he was slow to recognize the earmarks of dishonesty. France admired those who quarreled with her own enemies; largely for this reason did France, as a nation, aid the American colonies. The French minister, however, did not hesitate to open secret negotiations with the British, that he might further the interests of Spain. Already Spain owned the region west of the Mississippi and proposed in the *sub rosa* dealings to extend her possessions to include the whole Mississippi basin from the headwaters of that river eastward to the western end of

[5] Judson Harmon, *Ohio Centennial Anniversary Celebration*, 1903, p. 63.

Lake Erie and thence across the mountains to Florida. Another of our peace commissioners, John Hay, who had been in Spain, became aware of the duplicity of the French minister, and brought the matter to the attention of Franklin, who at first was unwilling to believe it. But Hay persisted, and sent an agent to England to secure further proof, if possible. John Adams, our third commissioner, agreed with Hay. The surreptitious plans of Spain and France were of no avail. When the Treaty of Paris was signed, the new Republic owned the continent between Florida and the Great Lakes to the Mississippi. George Rodgers Clark, under his commission from the governor of Virginia, had held the territory which the three nations wanted. If he had not done this, Virginia could not have exercised nominal control of the territory during the war, and our commissioners would have had slight grounds for claiming it in the peace negotiations.

CLAIM OF THE UNITED STATES CONGRESS

At the close of the Revolutionary war the thirteen original colonies were states, and among themselves the question came up as to their western boundary. Much contention had arisen over the western country after the French and Indian war. All the colonies, however, were united against King George; and, while opposing a common foe, there was little mutual strife. Congress, therefore, had to deal with several contesting claims to lands west of the Appalachians. The English officials in Canada, and at a few posts south of the Great Lakes, expected a quarrel among the young states. England, for many years after the Peace of Paris, 1783, continued to hope for a recurrence of strife, the outcome of which would be different. According to the custom in Europe, a treaty merely meant an opportunity for the contending factions to strengthen themselves and then renew the fight. England anticipated factional disputes in this young family of states; then England's emissaries would arrange an alliance with one faction, hoping to again get possession of these lost colonies.

State claims conceded to the federal government. Of the several states that had claims west of the Appalachians, Virginia apparently had the best. A quite definite charter and a very distinct conquest of the area during the Revolutionary war

enabled Virginia's lawyers to make out a good case. On the other hand, New York State felt that it also had an exceedingly good title to part of the territory west of Pennsylvania, a title which was satisfactory to the English jurists: the deed given by the Iroquois confederacy to the English governor of the colony which had now become the state of New York.

Congress could do little if the commonwealths were to become embittered over such dissensions. This was the time for magnanimity. New York State was the first to relinquish to Congress her title to the disputed territory. Not to be outdone in acts of patriotism, Virginia, through Governor Thomas Jefferson, deeded to Congress her possessions north of the Ohio river. If the two states which had the best claim on this territory yielded their title to Congress, it were indeed petty for the other states to offer further obstruction. The English were again disappointed; the dissensions gave way to higher motives.

The Northwest Territory. The necessity for the United States Congress coming immediately into legal possession of that territory was financial. The Revolutionary war closed with the defeated army of a resourceful nation on one side, and the victorious army of a bankrupt people on the other. The Continental Congress had borrowed of all of its loyal citizens at home and British haters abroad. At once Congress arranged to dispose of this western property, that the new Republic might raise the funds to meet imperative obligations.

The creation of the Northwest Territory and the beginning of regular settlements in Ohio were about coincident. Congress made General St. Clair governor of the western lands, and issued a proclamation, warning all disorderly persons out of the area. Congress, about the same time, also provided for a survey of the region, that the land might be definitely laid out and turned over to prospective purchasers.

Summary

Some of the geographic features of North America as a continent have been noted in the early history of the Ohio country. The prehistoric inhabitants of the area probably came from the west, having spread across the central Mississippi basin. North of the Ohio river there were frequent changes in Indian suprem-

acy, because it was impossible to successfully guard the region against invasion, except on the east; even on that side the French were not able to hold Ft. DuQuesne against the British. The St. Lawrence and the Mississippi rivers aided European explorers in penetrating the continent; citizens of France were the first to investigate the St. Lawrence, and their activity centered in its basin till the whole region was won by England.

Any people inhabiting the northern colonies eventually would be enticed westward through the Mohawk gap, thence along Lakes Ontario and Erie into the Ohio country. The Appalachian barrier checked the youthful energy of the early English explorers and nurtured the coast settlements into the nucleus of a strong nation. The more difficult passes, and broader wilderness belt south of New York did not permanently restrain the hardy frontiersmen.

Because of its geographic environment, the land between Lake Erie and the Ohio river has supported a succession of inhabitants, and been subject to several rulers:

1. The Ohio area was first occupied by people of whom we know nothing; books simply speak of them as "prehistoric." Ownership must have been well established by this unknown people; there is scarcely a county of the state in which their works are not found, representing great labor. Whoever these early inhabitants were, they worked. Whatever may have been their purpose, this labor represents some motive that must have actuated them as a people. The great earth structures that abound, adjacent to, and in many of the wide fertile valleys of Ohio, less frequently on the intervening hills, represent more than individual ambition. This must have been an ambitious people; their mute testimonials will long endure. The location of their more extensive works reflects the influence of topography; later inhabitants have very often selected the same sites. Possibly these prehistoric settlers had to contest the ground with earlier inhabitants, or to repel invasion.

2. After these came the American Indians, who were scattered about the state when the first white man visited the area. Their ownership was based on "squatter sovereignty" which, under some restrictions, has usually been a sufficient title among English peoples. The Indians of Ohio never occupied the territory long in peace; they were frequently harassed by the strong Iro-

quois Confederacy. Furthermore, they were hemmed in on the south by the Cherokees, who were often aggressive. So Ohio was never held continuously nor controlled by a particular tribe of Indians. Its physiographic environment invited conquest. The Ohio river was no barrier, but rather a route of approach for southern tribes; and Lake Erie made the area very accessible for the predatory bands of New York. Without the restraints of civilization, the Ohio country would never have become prosperous; but under stable conditions, the geographic features that formerly invited chaos have become a very important asset.

3. Next the French felt that they had acquired title to this region. Spurred by the trade efforts of Governor Dongan of the New York colony, the French pushed their permanent forts farther south, and then established trading posts through Ohio. They possessed the territory, therefore, so far as trade relations were concerned. In addition, they usually showed some spiritual concern for the Indians and ministered to them in this state, as elsewhere. The first whites to discover Ohio were the French.

4. The English kings issued charters to their subjects, disposing of territory which embraced Ohio and all the country west. These paper concessions were at variance with the fact of French possession, but for a long time geographic conditions averted collision. Slowly the interests of the two peoples came into conflict; the relief features of the French territory had imposed no barriers, but did encourage a scattering of energy; in the struggle, the French were the weaker.

5. By the Treaty of Paris, 1763, England became the legal owner of the trans-Appalachian country; this treaty was acknowledged by all Europe. Therefore, from the standpoint of European methods, England won the first title.

6. For some time before, and more numerously after, this transfer to the English, frontiersmen from the colonies came into the territory, and took possession without legal process. Such a procedure was one of their purposes in their final struggle with France. Many of the colonies maintained that some of the area across the mountains was theirs by charter grants. King George did not sanction this settlement of the West; his Quebec Act was one of the many causes that led to the Revolution. The colonies, winning in this war, and becoming states, again announced their claims.

7. Shortly after the close of the Revolution, this region, including the concessions of the individual states, became the property of the United States Congress, and was organized as a territory. In 1803, a portion of this Northwest Territory became the state of Ohio.